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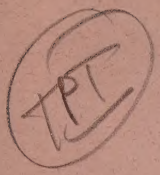


# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY.

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APPENDIX TO VOL. LX.

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## TOTAL SOLAR ECLIPSE OF 1900, MAY 28.

## PRELIMINARY REPORTS ON THE BRITISH GOVERNMENT EXPEDITIONS.

The present number of the MONTHLY NOTICES being the last of Vol. LX., Subscribers (not Fellows) are requested to take notice that the Subscription for Vol. LXI. (10*s.*, including postage) has now become due, and should be forwarded to the Assistant-Secretary, Mr. W. H. WESLEY, Burlington House, London, W.

# MONTHLY NOTICES

OF THE

# ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

*FROM NOVEMBER* 1899 *TO NOVEMBER* 1900.

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## VOL. LX.

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MONTHLY NOTICES

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APPENDIX TO VOL. LX.

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"Total Eclipse of the Sun, May 28, 1900. Preliminary Account of the Observations made by the Solar Physics Observatory Eclipse Expedition and the Officers and Men of H.M.S. 'Theseus,' at Santa Pola." By Sir NORMAN LOCKYER, K.C.B., F.R.S. Received June 22, 1900.—Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900.

The observing station selected for my party was determined upon from information supplied by the Hydrographer, Rear-Admiral Sir W. J. L. Wharton, R.N., K.C.B., F.R.S. Santa Pola appeared likely to meet the requirements of a man-of-war, and without such assistance as a man-of-war can render, the manipulation of long focus prismatic cameras in eclipse observations in a strange country is impracticable.

Santa Pola lies very near the central line of the eclipse, and good anchorage was available, protected from some winds.

Before leaving England, I communicated with Professor Francisco Iñiguez é Iñiguez, Director of the Madrid Observatory, and Mr. Jasper Cumming, H.M. Vice-Consul at Alicante. These gentlemen, together with Don José Bonmati Mas, a large landed proprietor, and father of the Mayor of Santa Pola, very kindly made all the necessary preliminary arrangements with the local authorities, who had also been instructed by the Spanish Government, after representations had been made by the Foreign Office, at the request of the Royal Society.

As a result of the Royal Society's application to the Admiralty, H.M.S. "Theseus," commanded by Captain V. A. Tisdall, R.N., was told off to meet the expedition at Gibraltar, and convey the observers to Santa Pola.

The expedition consisted at first of Dr. W. J. S. Lockyer, from the Solar Physics Observatory, Mr. A. Fowler, the demonstrator in Astronomical Physics, from the Royal College of Science, and Mr. Howard Payn, who joined as a volunteer; I subsequently received orders to accompany and take charge of it.

Mr. Payn went on in advance overland to make preliminary arrangements and to lay out the camp on a plan which had been previously arranged, while the remaining observers left England on May 11, by the R.M.S. "Oruba," of the Orient line.

On arriving at Gibraltar, the party at once went on board H.M.S. "Theseus," and left for Santa Pola, which was reached just before noon the following day, May 17. I was glad to find that great interest had been shown in the expedition before our arrival on board, and that lectures on the work to be undertaken had already been given by the Chaplain, the Rev. G. Brooke-Robinson, M.A.

Assistants were at once forthcoming for working the prismatic cameras, and also for manipulating several cameras which I had brought out to be used by the ship's company in obtaining photographs of the corona.

Observing parties in charge of officers of the ship, to make observations along several lines, were at the same time organised.

On our arrival at Santa Pola, the following local officials came on board with Mr. Payn:—Sns. Francisco Bonmati Mas, Mayor of Santa Pola; Antoine Bonmati Mas, Vice-Mayor of Santa Pola; José Bonmati Mas, Municipal Councillor; José Salinas Perez, Municipal Councillor; Eladio Ponce de Leon, Secretary to the Mayor; Michel Sempere, Justice of the Peace; José Hernandez, Captain of the Port; Geronimo Agnati, Administrator of Customs; Eduard Fernandez, 1st Lieut. of Coast Guards; Tomas Bueno, Medical Officer.

They informed us that permission had been given for landing parties from the man-of-war, and special facilities granted for landing instruments and personal baggage without Custom's examination.

The erection of the instruments, huts, and tents was commenced on

the following morning, May 18, and by the evening of May 21 the principal instruments were reported in approximate adjustment. Drills were begun on May 22, and were carried on several times a day up to the day of the eclipse. In this work the eclipse clock, which I have described in previous eclipse reports, was used.

By permission of the Captain, three of the officers of the "Theseus," Lieuts. Andrews, Doughty, and Pattrick, R.N., occupied quarters on shore to superintend the work of the parties in the camp. On board, the Chaplain gave instructions in sketching coronas and recording stars, using for this purpose a lantern which had been placed at the disposal of the expedition by the Orient Steam Navigation Company.

The weather was very favourable for the work of the expedition, but at times the landing and embarking of parties from the ship was rendered difficult by strong sea breezes and the consequent surf.

Both day and night the instruments were carefully guarded by a detachment of "Guardias Civiles," told off for the purpose by the Spanish authorities.

The groups of observers were as follows:—

LIST OF ECLIPSE PARTIES.

*Timekeepers.*

Lieut. F. A. Andrews, R.N.
Mr. Boughey, Mid.
Mr. Lambert, Mid.
J. Wale, 2nd Yeoman Signals
W. Webb, P.O. 1.
Bugler Sneller, O.S.

*6-inch Prismatic Camera.*

Dr. Lockyer.
S. Birley, E.R.A.
J. Green, A.B.
C. Fishenden, O.S.
C. Willmott, O.S.
A. Humphries, O.S.
G. Hyatt, O.S.

*20-foot Prismatic Camera.*

Mr. Fowler.
W. F. Cox, Armr.
A. Whitbourne, A.B.
F. Burt, A.B.
A. Maskell, A.B.
E. Davies, O.S.
H. Cristopher, O.S.
W. Harrison, Sto. Mech.

*4-inch Equatorial.*

Sir Norman Lockyer, K.C.B.
C. C. Lambert, Mid.

*$3\frac{3}{4}$-inch Equatorial.*

Lieut. H. M. Doughty, R.N.
A. G. N. Lane, Mid.

*Long-focus Coronagraph.*

Mr. Payn.
T. McGowan, A.B.
E. Woodland, A.B.
H. Eary, A.B.
W. Mann, O.S.
H. Brooks, O.S.

*Graham Coronagraph.*

Mr. W. J. S. Perkins, Asst. Engr., R.N. J. Knowles, Chief Stoker.
W. Walker, Lg. Stoker.

*De La Rue Coronagraph.*

Mr. H. W. Portch, Asst. Engr., R.N. H. Frost, Chief Stoker.
W. Waterfield, E.R.A.

*Dallmeyer Coronagraph.*

Surgeon J. Martin, R.N. R. Quint, Chief Stoker.
E. Buckingham, E.R.A.

*Discs.*

Mr. J. B. Bateman, Mid. R.N.
W. Fraser, Arm. Crew.
R. S. Bradbrooke, A.B.
— Mr. J. A. Daniels, Torp. Gunner, R.N.
G. Fair, Armourer.
E. Gordon, S. Carp.

H. W. Richardson, P.O. 2.
E. Voyle, Lg. Shipwt.
T. Orange, Boy, 1 c.
— W. Tucker, A.B.
W. Brewer, A.B.
B. Salmon, Boy, 1 c.

A. Mason, A.B.
A. Steven, A.B.
C. Paul, Boy, 1 c.
— A. May, A.B.
H. Bailey, A.B.
J. Entwistle, S. Std. Boy.

*Sketches of Corona without Discs (on shore).*

W. Butt, M.A.A. H. Meacher, Pte. R.M.L.I.
G. Guilliame, A.B. H. Schmidtœl, O.S.

*Sketches of Corona without Discs (on board).*

W. Baxter, A.B. J. Wheeler, Pte. R.M.L.I.
W. Butts, Pte. R.M.L.I. E. Willis, S.B. Attendant.
C. Jacob, Pte. R.M.L.I.

*Observations on Stars (on shore).*

Mr. Bennett, Clerk. H. Angus, O.S.
W. Riches, L. Seaman. W. Kinvett, Pte. R.M.L.I.
A. Pontifex, A.B. W. Oliver, Pte. R.M.L.I.
W. Bosworth, A.B.

*Observations on Stars (on board).*

Rev. G. B. Robinson, M.A. E. Hammond, Sto.
H. Croxon, S. Corpl. G. Andrews, Sto.
A. Phillips, Leading Shipwt. G. Nightingale, Sto.
R. Vigus, Corpl. R.M.L.I. S. Wilson, Sto.
E. Price, Pte. R.M.L.I. E. Savage, Pte. R.M.L.I.

*Observations of Shadow Bands (on shore).*

Commander Hon. R. F. Boyle, R.N. Mr. J. G. Walsh, Mid. R.N.
Mr. T. Slator, Naval Instructor, R.N. Mr. F. C. Skinner, Mid. R.N.

*Meteorological Observations (on shore).*

Lieut. Pattrick, R.N. Mr. G. S. Hallowes, Mid. R.N.

*Meteorological Observations (on board).*

G. Donnelly, Yeom. Sig. W. Hearne, Sig.
E. Gant, Lg. Sig. J. Beach, Sig.
A. Enstidge, Sig.

*Landscape Colours (on shore).*

Capt. F. V. Whitmarsh, R.M.L.I. Lance-Corpl. Wade, R.M.L.I.
Ship's Steward D. Green. W. Birkett, Writer.

*Landscape Colours (on board).*

Fleet Paymaster A. W. Askham, R.N. Lieut. W. J. Frazer, R.N.

*Shadow Phenomena (on shore).*

Mr. C. Prynn, Carpr. R.N.

*Shadow Phenomena (on board).*

Lieut. H. R. Shipster, R.N.

*Photographers.*

J. Knight, S.B. Steward. B. Bulbrook, A.B.

*Aide-de-Camp to Sir Norman Lockyer, K.C.B., F.R.S.*

Mr. C. C. Lambert, Mid. R.N.

*Time Arrangements.*

According to the Admiralty chart, the latitude and longitude of the place of observation are 38° 11′ 20″ N. and 0° 33·66′ W. respectively. For this point, the times and position angles of contact derived from the formulæ given in the 'Nautical Almanac Circular,' No. 17, were as follows:—

Beginning of totality, May, 28 d. 4 h. 12 m., 51·7 s.
End „ „ 4 h. 14 m., 10·5 s.
Duration of totality ..... 1 m., 18·8 s.
Position angle of first contact, 87° 3·5′ from N. towards W.
„ „ last „ 93° 47·3′ „ „ E.

The experience of the Indian eclipse of 1898 suggested that the duration of totality was too long, and for the practical working during the eclipse the adopted time was 75 seconds, so that there would be no chance of spoiling the coronagraph plates by exposing them after totality. The face of the eclipse clock was graduated accordingly.

The arrangements for securing signals at definite intervals before totality was identical with that employed in Lapland and India. An image of the sun projected by the finder of the 6-inch two-prism prismatic camera was viewed on an adjustable screen, marked in such a way that it was easy to see when the cusps subtended angles of 90°

and 55°, which occurred respectively at 16 secs. and 5 secs. before totality. The signals "Go" at the commencement of totality, and "Over" at the end, were given by myself, from observations made with the 4-inch Cooke telescope.

*Results.*

Some of the photographs have not yet been developed, and the reports have not yet been received from the ship's parties, so that only a very brief reference to the work accomplished is possible.

*The Prismatic Cameras.*

The discussion of the series of photographs taken with the prismatic cameras employed in the last three eclipses indicated that continued work with this form of spectroscope should be undertaken, (1) with the view of obtaining data strictly comparable with the previous photographs, and (2) that an effort should be made to extend the inquiry into comparative lengths of the various arcs. For the first purpose it seemed desirable to repeat the Indian work with the 6-inch camera having two prisms, while for the second an instrument of longer focus was necessary.

Representations as to the importance of the latter instrument were made to the Royal Society, and ultimately the purchase of a Taylor triple lens of 6 inches aperture and 20 feet focal length was authorised. This was received so shortly before the expedition left England, that it was only possible to make a rough trial of the instrument before it was set up at Santa Pola. Both prismatic cameras were worked in conjunction with siderostats, calculations having shown that the position angles of contact were favourably situated after reflection.

Dr. Lockyer took charge of the two-prism instrument, and Mr. Fowler of that having a long focus, and in each case the programme of exposures was successfully performed.

The photographs which have been developed indicate the same succession of phenomena recorded in the three previous eclipses, but the recent eclipse was specially advantageous, for the reason that the chromospheric arcs at the instant of contact were of greater length.

A very complete record of the spectrum of the chromosphere at various depths has been secured with both instruments, and it seems probable that new information as to the distribution of the various vapours will be furnished by the photographs taken with the long-focus instrument.

The spectrum of the corona shows the green ring at 5303·7, the blue ring at 4231, and the violet ring at 3987·0: others may possibly appear on closer examination. All the rings are of totally different character from the chromospheric arcs, and have their greatest bright-

ness in regions other than those where the chromospheric arcs are brightest. As before, 3987·0 is much more uniform in brightness throughout the extent of the ring than the others; 5303·7 is especially strong in one or two regions; but on the whole is probably weaker than in 1898.

The photographs show that the scale of the spectra is by no means too large for work with short exposures with a lens of 6 inches aperture. The spectra are 7·5 inches long from $D_3$ to K, and the diameter of the rings is 2·5 inches; photographs taken with an exposure estimated at $\frac{1}{4}$ of a second are fully exposed.

*The Differences between the Coronas observed at the Periods of Sun-spot Maxima and Minima.*

My attention was called especially to these differences, because I saw the minimum eclipse of 1878, while the phenomena of that of 1871 (maximum) were still quite fresh in my mind. My then published statements have been amply confirmed during the eclipses which have happened since 1878, but certainly the strongest confirmation has been obtained during the present one, which took place two more spot periods after 1878.

1. *Form.*

With regard to form, at the instant of totality I saw the 1878 corona over again, the wind vane appearance being as then most striking.

2. *The Spectrum.*

In connection with the eclipse of 1878 (minimum), I pointed out that, whereas in 1871 (maximum) the spectrum of the corona viewed by small dispersion was remarkable for the brightness of the lines; in 1878 they were practically absent, and the continuous spectrum was remarkably brilliant.

I determined therefore to make a similar observation in this year of maximum, and, as in 1878, used a grating first order spectrum placed near the eye. The result was identical with that recorded in 1878. I saw no obvious rings or arcs, but chiefly a bright continuous spectrum.

3. *The Minute Structure of the Inner Corona.*

Lieut. Doughty, R.N., and myself made observations on the minute structure of the corona, in order to see if any small details could be observed, and whether they were the same as those I saw so well and recorded during the eclipse of 1871, at a period of sun-spot maximum. This question was specially taken up this year, as exactly two sun-spot periods have elapsed since 1878.

In 1871 I used a 6-inch object glass, and distinctly observed marked delicate thread-like filaments, reminding one of the structure of the prominences, with mottling and nebulous indications here and there; some of these distinct markings were obvious enough to be seen till some minutes after totality.*

This year, with a perfect 4-inch Taylor lens and a high power, not the slightest appearance of this structure was to be traced; the corona some 2′ or 3′ above the chromosphere was absolutely without any detailed markings whatever.

Lieut. Doughty duplicated and confirmed these observations with a $3\frac{3}{4}$ Cooke. Here, then, is established another well-marked difference between maximum and minimum coronas.

*The Coronagraphs.*

Four coronagraphs were employed of various apertures and focal lengths. One, of 4 inches aperture and 16 feet focal length, was in charge of Mr. Howard Payn, while the others were controlled by officers of the ship.

The results obtained are very satisfactory, those taken with the long-focus instrument being especially good. In this case the image is $1\frac{3}{4}$ inches in diameter, and the definition is perfect. The photograph taken with an exposure of 5 seconds shows a great wealth of detail in the inner corona and prominences; the fine definition appears to be due to the fact that a Taylor photo-visual lens was employed, bringing the rays of various refrangibilities to the same focus. A long exposure photograph, with the same instrument, is remarkable for the perfect hardness of the moon's edge, notwithstanding the motion during totality.

The three photographs secured by Asst. Engineer Portch, R.N., with the De la Rue lens of $4\frac{5}{8}$ inches aperture, give also sharp images with much fine detail.

Sandell triple-coated plates were used with this instrument.

With the 6-inch Dallmeyer lens, two photographs on Sandell plates were obtained by Dr. Martin, R.N., one being exposed for about half a second, and another for 50 seconds.

The longer exposure records the extensions to a greater distance from the dark moon than any of the other photographs obtained, with the exception of the one secured with the small-grating camera.

This last-mentioned instrument consisted of a Zeiss anastigmatic lens of 9 inches focal length, with a small Thorp grating mounted in front of it. The exposure of the plate was 40 seconds during totality; the longest streamer in the N.E. quadrant extends to a distance of $4\frac{1}{2}$ lunar diameters.

* 'Solar Physics,' p. 372.

*Discs.*

Six discs for cutting out the bright light of the inner corona were erected, with the view of enabling the observers to detect the long extensions if there should be any. They were very carefully set up by Lieuts. Doughty and Andrews, R.N., and were provided with eye-pieces having all necessary adjustments. Mr. Daniels, torpedo gunner, then took charge of the party, and numerous rehearsals were given. In the trials remarkable skill in recording delicate details was displayed.

During the eclipse, the actual observer was blindfolded for five minutes before totality.

No extensions of the nature observed by Professor Newcomb in 1878 were recorded.

*Observations on the Stars Visible during Totality.*

A large party for the observation of stars visible during totality was trained and organised by the Chaplain, Rev. G. Brooke-Robinson R.N., who was provided with a set of star charts for purposes of instruction prior to the eclipse, and another set, prepared by Dr. Lockyer, for making records during the eclipse.

Venus became visible at a very early stage of the eclipse, and during totality Mercury was a very conspicuous object near the extremity of one of the streamers. $\alpha$ Tauri, $\alpha$ and $\gamma$ Orionis were also recorded. No comet or unknown body was noted.

*Shadow Bands.*

The Naval Instructor on H.M.S. "Theseus," Mr. T. Slator, B.A., undertook this branch of the eclipse work, and during the eclipse worked in conjunction with the Commander, the Hon. R. F. Boyle. Very complete arrangements were made for securing the orientation of the bands (1) on a horizontal plane; (2) on a plane in the meridian; (3) on a plane in the prime vertical. The bands appear to have been very ill-defined, but the necessary observations were secured in planes 1 and 2.

*Meteorological Observations.*

A regular series of observations of temperature and pressure was established three days before the eclipse, and continued until two days after; Lieut. Pattrick, R.N., taking charge of this branch of the work. During the eclipse the temperature fell 5° C., and the barometer also fell slightly.

The thanks of the expedition are due especially to those named in

the foregoing account, not only for assistance rendered, but also for their great kindness to us. I have already, in a letter, expressed to the Royal Society my deep sense of the obligation they have laid us under.

As in the case of the "Volage" and "Melpomene," the officers and men of the "Theseus" not only assisted us with certain instruments, but organised crews for others, and many lines of work which it was impossible for the observers sent out from England to attempt. Their skill, resourcefulness, and steadiness were alike truly admirable.

Thanks are also due to the Managers of the Orient Steam Navigation Company, who conveyed the instruments to and from Gibraltar freight free.

I may add, the Civil Governor of the Province of Alicante, Señor don Hipoldo Caras y Gomez de Andino, visited the camp to assure himself that all the assistance the Spanish authorities could give had been rendered.

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"Total Solar Eclipse of 1900 (May 28). Preliminary Report on the Observations made at Bouzareah (in the Grounds of the Algiers Observatory)." By Professor H. H. Turner, M.A., F.R.S., and H. F. Newall, M.A., Sec. R.A.S. Received June 28,—Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900.

The Report is presented in three parts.

Part I. Origin of the Expedition and General Preparations by the Two Observers jointly (§§ 1—10).

Part II. Separate Report by Professor Turner.

§§ 11—12. The Cameras and Cœlostat.
§ 13. The Polariscopes.
§§ 14—16. Adjustments.
§§ 17—19. Programme of Observations.
§§ 20. The Standard Squares.
§ 21. Use of Green Screen.
§ 22. Integral Photometer.
§ 23. Development.

Part III. Separate Report by Mr. Newall.

§ 24. The Four-prism Spectroscope with Slit.
§ 25. The Photographic Camera with large Objective Grating.
§ 26. The Polariscopic Camera (Savart Plates and Nicol Prism).
§ 27. Atmospheric Polarisation.
§ 28. General Observations.

## Part I.

1. *Origin of the Expedition.*—This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The expedition was most cordially and hospitably assisted by M. Trépied, the Director of the Algiers Observatory, and the observers are indebted to him in numberless ways for his kindness. He assigned good positions for the instruments in the Observatory grounds, and had brick piers built beforehand according to plans supplied to him by the observers. He made the arrangements for conveying the instruments to and from Algiers; and put at the disposal of the observers a capacious dark room (which we believe he had specially arranged for the purpose) and the services of a carpenter.

2. *Mr. Wesley's Observations.*—It may be here mentioned, although it does not come strictly within the scope of this report, that M. Trépied allowed Mr. W. H. Wesley, the Assistant Secretary of the Royal Astronomical Society, who has had great experience in drawing the corona from photographs, to use the equatorial coudé of the Algiers Observatory during this eclipse; and Mr. Wesley was thus enabled to make his first eye observations on the corona itself under most favourable conditions. He joined the present expedition, but as he was the emissary of the Royal Astronomical Society and not of the Joint Committee, the report of his observations is not included here. That M. Trépied should have placed the finest instrument in the Observatory at the disposal of a foreigner is a striking instance of his scientific liberality; and the observers call attention to it because it will indicate more clearly than any enumeration of details the kind of assistance for which they have to thank him.

3. *Personnel.*—The following persons took part in the expedition:—

H. H. Turner, M.A., F.R.S., Savilian Professor of Astronomy at Oxford.

H. F. Newall, M.A., Sec. R.A.S., Observatory, University of Cambridge.

4. *Itinerary.*—The observers left Charing Cross at 11 A.M. on Saturday, May 12. They spent one day in Marseilles, and arrived at Algiers on Tuesday, May 15, proceeding in the evening of the same day to the little village of Bouzareah, which they made their headquarters, about a mile from the Algiers Observatory. The instruments had been sent round by sea (through the Papayanni Steamship Company), and should have arrived on May 10, but for some reason they did not arrive until May 17, and were delivered at the Observatory on the evening of May 18. Three whole working days of the eleven which had been

counted on were thus lost, and in order to carry out the programme an undesirably great press of work was necessary. The day of the eclipse was fine, and many good photographs were obtained. The development of these and the packing up of the instruments fully occupied the observers till Friday, June 1. They left Algiers on Saturday, June 2, and arrived in London on Monday, June 4. But they would record the opinion that the time spent on the expedition was too short. The work was got through, but with practically no margin for contingencies, and would have been done better with another week at least.

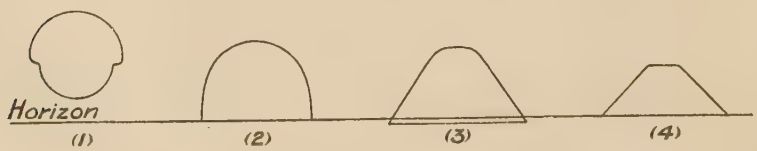
5. *Position of Station.*—The station was on the west side of the equatorial coudé, and about 50 yards S.E. of the transit-circle, the position of which is

Longitude..... $0^h12^m8^s\cdot7$ E. of Greenwich.
Latitude ..... $36^\circ\ 48'\ 0''\cdot5$ N.
Height above mean sea level, 1123 feet.

This spot was some distance from the central line, and 4 or 5 seconds of the 70 seconds of totality available were thus lost; but the loss was more than counterbalanced by the many advantages of being at a fixed observatory.

6. *Meteorological Conditions.*—As regular meteorological observations were made at the Observatory, none were made by us. The day of the eclipse was the finest of our stay, and fine days preceded and followed it. On May 26, 27, and 28 the sun was seen to set in the sea, and the "green ray" was looked for and seen by several observers.

The disc, when near the horizon on May 28, assumed remarkable shapes, of which the following four types were noticed by several observers :—




There was at times considerable wind, as M. Trépied had warned us, but the day of the eclipse was calm.

7. *Instruments, &c.*—(See separate reports of observers.)

8. *Huts.*—Willesden canvas over wooden framework was used, and found very satisfactory, as before.

Mr. Newall's hut was designed for his particular instruments, and the openings were obtained by leaving the canvas loose in the form of flaps, which were tied in the proper positions, either open or closed.

Professor Turner's hut was designed for general requirements, and has now been used, not only in this expedition, but as a transit hut in the determination of the longitude of Killorglin by the staff of the Royal Observatory, Greenwich, in 1898. As it appears to satisfy the conditions, the following notes of its structure may be useful to others :—

It is a skeleton wooden framework filled in by a series of panels, any one of which is removable without disturbing any other by simply taking out two screws. The panels forming the sides drop into a groove running round the base, and two screws are sufficient to hold them at the top. For the roof panels it is the upper edges which push into grooves along the central ridge, and the two fixing screws are near the eaves.

The panels themselves are rectangular wooden frames with canvas stretched over them. For transport, the sides are unscrewed, and then the canvas is rolled round the ends like a window blind.

The screws which fix the panels in position in the hut terminate in rings instead of the ordinary screw heads, so that they can be screwed up or unscrewed with the fingers instead of with a screw-driver, which may not be handy at the moment.

It may be remarked that both the huts were securely fastened down on this particular occasion, as the wind sometimes blew a gale.

9. *Assistance.*—The observers were assisted in the exposures as follows :—

Mr. H. Wyles, of the Leeds Astronomical Society, counted seconds aloud from a metronome.

Mr. J. Potter, of Leeds, carried from Mr. Newall's hut the information of the setting of the Savart prism (which Mr. Newall was to observe during totality) to Major K. O. Foster, who set the corresponding instrument in Professor Turner's hut (see separate report of Mr. Newall). It was originally intended to shout this information, but as it was found in the rehearsals that there was occasionally difficulty in hearing, Mr. Potter undertook this conveyance as a safeguard. As the event proved, his assistance was all important, for at the actual eclipse there was so much noise from other observers in the neighbourhood that the shout was not heard at all.

Major K. O. Foster, F.R.A.S., set Mr. Newall's savart between the second and third exposures, and at the same time changed the slit of Professor Turner's polariscope. He also uncovered the plates for long exposure soon after the beginning of totality and covered them before the end.

Mr. F. L. Lucas, of Berkhamsted, made the exposures for Professor Turner at the objective.

Master Eric Henn handed the plates.

Mr. F. L. Crawford, of the Indian Civil Service (who had seen the

1898 eclipse at Berar), received the plates, recorded the times, and also exposed for 10 seconds the integral photometer.

Mr. Lovett Henn, of Algiers, made the exposures with the grating for Mr. Newall.

Mrs. Newall made observations of the atmospheric polarisation during totality.

At 15 seconds before totality, as shown by the diminishing crescent of the sun, Professor Turner called "Stand by"; at totality, "Start": when Mr. Wyles counted from the metronome steadily up to 80. Totality lasted 64 or 65 seconds, and the extra 15 seconds was required by Mr. Newall for exposures at the second "flash." The signals were given with approximate correctness, though, by an oversight, no one timed the interval between the "Stand by" and the "Start."

The operations were rehearsed several times on the day before the eclipse, and once or twice in dumb show on the actual day. It was not found possible to arrange for rehearsals earlier; but, with the exception of the omission just noticed, everything went off at the time without a hitch.

10. *The Day of the Eclipse.*—Perfectly clear all day—no anxiety. The contacts were not observed by us with special care as we had much else to do, and observations were being made by the staff of the Observatory. M. Sy kindly supplied the following predictions and observations:—

| | Predictions. | Observations. |
|---|---|---|
| 1st contact..... | $3^h\ 17^m\ 21^s$ | $3^h\ 17^m\ 18^s$ |
| 2nd ,, ..... | 4 29 25 | 4 29 27 |
| 3rd ,, ..... | 4 30 32 | 4 30 32 |
| 4th ,, ..... | 5 34 31 | 5 34 25 |

Local mean time ($12^m\ 8^s{\cdot}7$ in advance of G.M.T.).

Lamps were not needed during totality.

Owing to an accident (a signal being lost through noise made by others) the shadow was not observed. Major Kingsley Foster noticed the "shadow bands" on the white surface of the "double tube" near which he was stationed.

## Part II.—Separate Report by Professor Turner.

### *Instrumental Equipment.*

11. *The Cameras.*—The double camera used at Fundium in 1893 (by Sergeant Kearney), and at Sahdol in 1898, was modified on the present occasion. One of the 7 × 7-inch tubes contained, as before, the photo-heliograph objective No. 2 of 4 inch aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of $7\frac{1}{2}$ inches focus placed

5 inches within the focus, giving an image of the sun $1\frac{3}{8}$ inches in diameter; but the "Abney" lens was no longer used in the other tube. It had been decided by the Joint Permanent Committee to discontinue the separate use of the two Abney lenses, and to recombine them into the original doublet, which Mr. Davidson was to use in the expedition organised by the Astronomer Royal. Hence the other half of the double tube camera was set free, and it was utilised to good effect by arranging *two* polariscopic cameras to give images on the same plate, a diagonal partition dividing the square tube into two. One instrument was arranged by Mr. Newall, and is described by him. The other was similar to the apparatus used by me in India in 1898, but with improvements in detail as described below. The double camera is furnished with six plate holders, each taking two plates of 160 × 160 mm. (as in use for the Astrographic Chart), both plates being exposed by a quarter turn of one shutter.

Alongside the double tube two other cameras were arranged for single exposures during the greater part of totality. One was a portrait lens of $5\frac{1}{4}$ inches aperture and 30 inches focus, stopped down to $f/8$; the other was a small polariscopic camera, described below.

12. *The Cœlostat.*—All these cameras were pointed downwards at an angle of 18° with the horizon, in azimuth 42° west of south, to the 16-inch cœlostat used in India in 1898. The mirror of this instrument was made by Dr. Common. It was silvered and sent out to Algiers by the Improved Electric Glow Lamp Company, and had a very fine surface. The mounting and clock of the instrument were made by Mr. J. Hammersley, from designs by Dr. Common. A steadier mounting is desirable on future occasions, though the present arrangement works well when there is not much wind to cause vibration.

13. *The Polariscopes.*—The arrangement used in India was as follows:—

(A) Objective, $3\frac{1}{2}$ inches aperture, 18 inches focus.
(B) Slit, of width 0·2 inch, in cardboard.
(C) Collimator, $1\frac{1}{2}$ inches aperture, $6\frac{1}{2}$ inches focus.
(D) Rhomb of spar, 1 inch aperture (clear).
(E) Camera, 2 inches aperture, 9 inches focus.

On the present occasion (E) was substituted for (A), which was of inconvenient width for the space at disposal. The primary image was thus reduced to half the size; but this had the advantage that a larger part of the image fell on the slit, the width of which remained the same as before, being governed by the focal length of the collimator and the angular separation of the images by the rhomb. The collimator (C) and the rhomb (D) remained unchanged, but the camera lens (E) was now a photographic objective of $1\frac{1}{2}$ inches aperture and 28 inches focus, made specially by Messrs. Cooke and Sons, of York.

The plate holder was of course that of the double tube, as above explained.

The slit (B) was arranged, as in 1898, in two portions, but was on this occasion made in brass.

The slit and rhomb were connected by a bar, and could be rotated sympathetically. They were set at such a position angle that the lines of the image parallel to the slit corresponded to vertical lines on the corona; but this setting was found after the eclipse to be not quite accurate. The setting was not changed during totality, but the slit was moved in the direction of its length, so as to give a different part of the field between the second and third exposures.

The small polariscope exposed separately resembles the objective prism spectroscope as opposed to the slit spectroscope. The reason for adopting the slit spectroscope form for the instrument above described is that the angular separation of images given by the large rhomb was not large, and if this rhomb had been simply placed in front of an objective, one image of the corona would have seriously overlapped the other. But a small rhomb (kindly lent me by Mr. Newall) gave a separation of $3\frac{1}{2}^{\circ}$, so that when the corona was viewed through this rhomb and an objective the two images polarised in perpendicular planes were clearly separated, though each was projected on the sky of the other. To cut out the sky backgrounds, a slit, of 1 inch aperture, was placed 15·7 inches in front of the rhomb.

*Instrumental Adjustments.*

14. *Adjustment of Cœlostat.*—The adjustment of the polar axis was made as described in the Report on the Japan Expedition,* by means of the attached declination theodolite. This was a new one, by Messrs. Troughton and Simms, of rather smaller size than the others, with a 3-inch circle reading to 1′ only. When the three eclipse cœlostats were constructed, theodolites were only supplied with two of them; and as in 1896 and 1898 there were two cœlostats at the same station, one theodolite sufficed for adjusting the two. But this arrangement was only provisional, and on the present occasion, when all three cœlostats went to different stations, it became necessary to provide the third theodolite. From previous experience I judged that the smaller size would be sufficient for the purpose.

The following observations will sufficiently indicate the state of adjustment, those with the level being made on the meridian and compared with the known latitude, so as to give the same sign to the errors as the sun observations :—

* 'Monthly Notices, R.A.S.,' vol. 57, p. 102.

| Date. | Sun's H.A. | Obs. decl. | Tab. decl. | O—C. |
|---|---|---|---|---|
| May 22..... | −3·0 | +20° 17′ | +20° 20′ | −3′ |
| | | Observation with level | | −1 |
| May 29..... | −1·0 | +21° 36′ | +21° 35′ | +1′ |
| | | Observation with level | | −1′ |

On the present occasion the cœlostat was not blocked with wood as in India; but it was found liable to slight vibration, and a firmer support should be provided for future eclipses.

15. *Tilt of Mirror.*—The time available for preparation was so fully occupied that no special observations for tilt of the mirror were made, but in India there was found to be no appreciable tilt.

16. *Focussing of Telescopes.*—The method adopted for the photoheliograph objective and magnifier was that described in the Report on the Japan Expedition.* The position found was very close to that found in previous expeditions. The object glass was unscrewed a quarter turn, *i.e.*, 0·02 inch, differing 0·02 inch from the position in 1898, as indicated by a wooden gauge.

The polariscopes were focussed on a distant view (a clear view of 7 or 8 miles across the bay was on this occasion available) through blue glass.

The portrait lens was first focussed by blue glass, and then three photographs of the distant view were obtained, which gave the focus sharply.

A focussing eye-piece made in blue glass, kindly lent by M. Trépied, was found very useful. I do not know whether this simple and convenient apparatus is well known; it is made by Hermagis, of Paris.

17. *Programme of Observations with Double Tube.*—The six slides of the double tube camera were filled with "Rocket" plates; four of them only were to be used during totality, the others being available for supplementary short exposures if time should allow. As it turned out, there was no time for more than the four, and the others were exposed just after totality. The actual exposures were as below :—

| No. of slide. | Exposure in seconds. | Time in beats from commencement of totality. | Time in seconds. |
|---|---|---|---|
| 1 | 1 | 6—7 | 5—6 |
| 2 | 5 | 13—18 | 12—17 |
| (Setting of Savart and slit between these.) | | | |
| 3 | 19 | 31—51 | 29—48 |
| 4 | 5 | 55—60 | 52—57 |
| End of totality | | 66 | 62 |
| 5 | 1 | 68—69 | 64—65 |
| 6 | 1 | 75—76 | 71—72 |

* 'Monthly Notices, R.A.S.,' vol. 57, p. 105.

The times after totality are diminished to get true seconds. The numbers in the third column are beats of a metronome, which, though adjusted beforehand, changed its rate, perhaps owing to the fall of temperature. Just after totality it was found to beat sixty-three times to the minute. Further, the word "One" was called on an actual beat which came about 0·5 second after the word "Start" (signifying the commencement of totality) had been called. This signal was given by me from a direct observation of the disappearance of the crescent, and agreed well with the observations of others. The signal for 15 seconds before totality was given to Mr. Newall by watching the length of the disappearing crescent on the focussing glass of the camera, and was approximately correct, though by an oversight no one observed the interval; but after giving this signal, as I found the direct light of the crescent did not hurt the eyes, I watched that in preference to the image on the glass. I saw the complete ring of the moon's disc quite 10 seconds before totality, and from that moment the corona seemed to grow out from the limb in a most beautiful manner.

18. *Programme for the Polariscopes.*—The two polariscopes mounted in the double tube had of course exactly the same exposures as above.

Between exposures of slides 2 and 3 the Nicol prism and Savart plate of Mr. Newall's polariscopic apparatus were rotated by Major K. O. Foster to the reading indicated by Mr. Newall's eye observations; and the slit of my apparatus was also moved by Major Foster to the second position, so that the second pair of photographs gave a different part of the corona from the first.

The smaller polariscope was exposed from 5 to 60 seconds, counting from the beginning of totality.

19. *Programme for the Portrait Lens.*—A Sandell triple-coated plate was exposed in this instrument. The exposure was made by Major Foster from 5 to 60 seconds, counting from the beginning of totality.

20. *The Standard Squares.*—On the six plates in slides, 1, 2, and 3, Sir W. Abney's "standard squares" were impressed for photometric observations of the corona. The exposures were to a standard candle at 5 feet from the plate, which is approximately twice as bright as the full moon. Assuming the brightest part of the corona to be as bright as the average surface of the full moon, the exposures to be given to the candle were calculated as follows:—

An image of the moon in the Dallmeyer lens of 4 inches aperture would be $1\frac{1}{2}$ inches in diameter. The illumination of the object glass is thus concentrated—

$$(4/1\tfrac{1}{2})^2 \text{ times} = 7 \text{ times}.$$

Hence the brightest part of the corona will affect the plate about seven times as much as direct moonlight, or three and a half times as much as a candle at 5 feet.

Hence to compare with a 1 second exposure to the corona through the lens, we should expose the plate to the candle for $3\frac{1}{2}$ seconds. Since the faintest of the standard squares obstructs some of the light, and since it is advisable to have an exposure on the plate from the standard light rather denser than the densest part of the image, the plates in slide No. 1 (to be exposed 1 second to the corona) were exposed for 6 seconds to the candle.

Those in No. 2 (to be exposed 5 seconds to the corona) were exposed for 40 seconds to the candle, and those in No. 3 (20 seconds to corona) for $2\frac{1}{2}$ minutes. These exposures are even longer, relatively, than No. 1; but on previous occasions the squares had not been dense enough, and it was considered advisable to make sure of going beyond the point required.

21. *Use of Green Screen.*—In slide No. 4 a coloured glass screen, kindly provided by Mr. Shackleton, was placed in front of the plate, with a view of obtaining information on the distribution of coronium in the corona by comparing a photograph taken in green light with the others. But owing to the following circumstance this particular experiment was not a success. The plate should of course have been one sensitive to green light, and some Cadett "spectrum" plates were taken out to Algiers for the purpose. They were whole plates and required cutting down to fit the slide. In the stress of other work the experiment was forgotten until an hour before totality. There was still plenty of time to fill the slide, and I went to the dark room to do so. But the circumstances were scarcely favourable for manipulating the diamond in the dark, as these plates require. The first plate broke and cut my finger, not seriously, but enough to hamper me, so that I had no better success in cutting another plate. Indeed, after one or two attempts I had to give it up. It seemed just worth while putting in a "Rocket" plate behind the green screen, but there was very little on the plate when developed; and the experiment was on this occasion of little or no value. I am sorry to have been unable to do justice to Mr. Shackleton's kindness in providing the screens, and hope that on another occasion I may make better use of them.

22. *An Integral Photometer.*—To obtain an estimate of the total light given by the corona, an Ilford "Empress" plate was exposed to its light for 10 seconds, in a small camera from which the lens had been removed, so that the corona shone directly on the plate, but side light was excluded. On the same plate standard squares were impressed by exposing it to the candle at 5 feet, as in § 8. The exposure given to the candle was, by an oversight, not recorded, but was either 10 or 20 seconds. The oversight was discovered before the eclipse, and another plate from the same batch was exposed to the candle and squares for 5, 10, and 20 seconds, and developed in the same dish. The effect of the corona was, however, considerably greater than that

of the 20 seconds' exposure through the thinnest of the square screens.

23. *Development.*—The plates in slide No. 1, and the corona picture of slide No. 2 (1 second), were developed with amidol: also the plate exposed to the integral photometer mentioned in § 12. All the others with metol.

## Part III.—Separate Report by H. F. Newall.

### § 24. *The Four-prism Spectroscope with Slit.*

It was intended to attempt—

(i) To secure photographs of the bright-line spectrum of the sun's limb at the beginning and end of totality, five photographs at the beginning, six at the end.

(ii) To photograph the spectrum of the corona in two separate regions of the corona.

It had been decided not to attempt to determine the velocity of rotation of the corona, for the duration of totality was not long enough to give satisfactory images of the lines in the spectrum of the corona at such distances from the limb as would ensure some measure of certainty that the observations would not deal with the local disturbances known to exist near the chromosphere.

The instrument arranged for the purposes above mentioned is a four-prism spectroscope with a single slit. It was used by the writer in India, at Pulgaon in 1898.* The only changes made in it were that (i) only one slit was used instead of two; and (ii) one of the prisms which had been found to give imperfect definition on account of want of homogeneity in the glass had been replaced by another prism. The prism box and train of prisms had been used at the Cambridge Observatory for a star spectrograph, and were dismounted, for use in the eclipse, after the completion of certain observations of Capella.

The train of prisms is of such dimensions and construction as to transmit a 2-inch beam of light, and to produce a minimum deviation of 180° for $H_\gamma$. The collimator and camera are set parallel to one another.

The whole spectroscope is mounted so as to turn about an axis parallel to the collimator. The axis is rotated (with a period of twenty-four hours) by clockwork, and is tilted so as to be parallel to the earth's axis. In this position the collimator points to the north pole, and the camera to the south pole.

The tube of the collimator is prolonged beyond the plane of the slit, and is arranged to carry at its end a mirror of speculum metal and an

* 'Roy. Soc. Proc.,' vol. 64, p. 55.

object glass, by means of which an image of the sun can be thrown upon the slit.

The whole arrangement thus consists of a spectroscope combined with a polar heliostat, and in virtue of the fact that the spectroscope is rotated together with the mirror, the image of any celestial object thrown upon the slit does not rotate relatively to the slit. Furthermore, the mirror is mounted in such a manner that the axis about which it can be tilted—namely, the declination axis—can be oriented relatively to the collimator tube, so that any diameter of the sun may be set parallel to the slit.

A special plate holder was designed for use in Algiers in order to facilitate the rapid change of plates. It was charged with twelve plates, fixed film outwards on the outside of a cylinder (2 inches in diameter), whose axis was set parallel to the focal plane of the camera and in the plane of dispersion, free to turn inside a slightly larger covering cylindrical case. The arrangement was turned by hand, and worked admirably well. It is, however, only suitable for narrow spectrum plates, and might be used with very small alteration for a film on celluloid, such as is used in hand cameras of the Kodak type.

The linear dispersion in the photographed spectrum is about 14 tenth-metres per millimetre at $H_\gamma$. The width of the slit was adjusted to 0·03 mm. by a diffractional method.

The scale of the photograph is such that one degree on the sky corresponds to about 9 mm. on the plate.

The effective aperture of the combination regarded as an instrument for producing monochromatic images of a slit-shaped region of the corona is $f/10$.

The adjustment of the axis of the instrument to parallelism with the earth's axis was accomplished in the same way as in India by means of a theodolite with declination circle and level, which was attached to a part of the frame of the spectroscope specially prepared for it.

Programme of exposures, &c.:—

I. *Spectrum of the Sun's Limb at the Beginning of Totality.*—Five exposures were made in 7 seconds, beginning 3 seconds before Professor Turner's signal "Start" was called, and ending as Mr. Wyles called the "fifth" beat of the metronome.

*Result.*—The developed photographs show that the first plate was exposed at exactly the right moment to catch the spectrum of the "flash." It is filled with bright lines, and shows the part of the spectrum between $H_\zeta$ (3900) and $H_\beta$ (4861). The best part of the spectrum is that between wave-lengths 4100 and 4650.

All the other four plates show bright lines, but the fall in the number of them is very abrupt between the first and the second plates.

II. *Spectrum of the Corona.*—Six seconds after Professor Turner's signal "Start" a plate was exposed for the spectrum of the corona, and

the exposure was continued for 49 seconds, ending when Mr. Wyles called "fifty-five."

*Result.*—The developed photograph shows the spectrum of the corona in two regions situated at the ends of a chord whose length is approximately equal to the radius of the moon's image.

The radial extension is even less than in Captain Hills's photograph taken at Pulgaon in 1898. There is an abrupt fall in the intensity of the marked continuous spectrum at about $2\frac{1}{2}'$ from the limb, and at $3\frac{1}{2}'$ from the limb the spectrum is invisible.

In the preliminary examination of the spectrum none of the ordinary Fraunhofer lines have been detected, a fact which is of remarkable import when considered in connection with the intensity of the polarisation of the light emitted from the corona. (See below, p. 364.)

In one of the spectra the hydrogen lines are very strong, viz., $H_\beta$, $H_\gamma$, $H_\delta$, $H_\epsilon$, and $H_\zeta$. In the other they are barely visible, $H_\gamma$ appearing only very close to the limb, and not extending more than about a quarter of a minute of arc. The helium lines are strong in one and barely perceptible in the other. In one the calcium lines H and K are intensely strong and broadened, though the edges are defined and the lines very much shifted towards the red end of the spectrum; in the other, the H and K lines are weak and well-defined narrow lines. It is important to note that the shift of the broad calcium lines is in the direction that one would anticipate if pressure were the cause of the broadening and of the shift. Whilst it seems clear that the presence of the hydrogen, helium, and calcium lines in one and not in the other of the two regions of the corona whose spectra have been photographed is probably due to a prominence, this explanation is difficult to reconcile with the signs of pressure above referred to.

There are several bright coronal lines discernible in both spectra; and in the neighbourhood of one of the lines, viz., that of wavelength 4231, there seem to be two dark lines, apparently the only absorption lines visible in the spectrum.

III. *Spectrum of the Sun's Limb at the End of Totality.*—Immediately after the end of the exposure of the plate for the spectrum of the corona, the image of the corona was readjusted on the slit, under unexpected difficulties however on account of the faintness of the light. Mr. Wyles called "sixty-four" as I reached the platform again to make the exposures, and the exposures were made as follows:—

Plate No. 7 at 65
" 8 " 66
" 9 " 67
" 10 " 68
" 11 " 69
" 12 " 70

and I gave the signal to Mr. Henn for his last exposure at 71.

It was found later that the faintness of the light was caused by a dark glass in front of the eye-piece, which was used for viewing the image on the slit. This was needed in the first exposures, but should have been removed by turning the hinged glass aside. It is evident from the photographs that the image was improperly adjusted in consequence of the faintness of the light; there is no impression on the plates.

The results obtained with the four-prism spectroscope may be summarised as follows: Five photographs of the spectrum of the vapours near the sun's limb at a fixed point, and a photograph of the spectrum of the corona at two points widely separated near the sun's limb.

### § 25. *The Photographic Camera with Large Objective Grating.*

Visual observations of the green coronal ring made at Pulgaon, India, 1898, January 22,* convinced me that the ring could have been photographed with the objective grating and telescope then used. Accordingly preparation was made to attempt a photograph with a large grating at Algiers. For this purpose, use was made of a plane grating by Rowland, 14,438 lines to the inch on a ruled surface $5 \times 3\frac{1}{2}$ inches, fitted on an axis in front of a telescope of focal length 68 inches and aperture 4 inches. The grating is a very brilliant one, and is ruled on an unusually fine-grained piece of speculum metal. The object glass is an excellent one by Cooke and Sons. Both of these belong to the splendid spectroscopic installation arranged by the late Professor Piazzi Smyth, with the aid of contributions from the Government Grant. The installation is now set up at the Cambridge Observatory, having been put at my disposal for spectroscopic investigations by the Royal Society. I am thereby put under a great obligation to the Society, and I venture to take this opportunity of making acknowledgment of it.

In the recent eclipse the sun was about as far to the north of the celestial equator as it was to the south in the Indian eclipse of 1898; accordingly the grating and telescope could be mounted in almost the same relative positions in Algiers as in India; it was only necessary to reverse the positions along the polar axis, and arrange that the telescope pointed towards the south pole instead of the north. Accordingly the instruments were mounted so that the telescope was parallel to the earth's axis and pointed downwards towards the south pole. For the purposes of taking photographs this position was extremely convenient.

A strong wooden bridge or yoke was fitted to the object glass end of the tube of the telescope, and projected in front of the object glass

* 'Roy. Soc. Proc.,' vol. 64, p. 58; and 'Mon. Not., R.A.S.,' vol. 58, App., p. (58).

at such a distance from it that the grating could be mounted free to turn on a spindle passing through the sides of the yoke at right angles to the collimation axis. A small brass cup or socket was attached to the middle point of the yoke so that it lay in the axis of collimation, and it was made the lower bearing, by which the whole instrument was supported on a pointed pivot, fixed, with a small amount of freedom for adjustment, on a low pillar of brickwork. The upper end of the tube of the telescope rested on antifriction rollers, supported on the west side of the higher pillar of brickwork, which also carried the four-prism spectroscope. Thus the polar axes of the two instruments, viz., the objective-grating camera and the mounting of the four-prism spectroscope, were side by side; and it was not a difficult matter to link together the two mountings by means of a connecting rod, so that the same clockwork should drive both. Each mounting was connected by slow motions with the one clock-driven sector, and so each could be adjusted relatively to the sun without disturbing the other. The arrangement worked admirably.

The light of the corona was incident on the grating at an angle of about 55°, and the diffracted beam utilised in the telescope left the grating at an angle of about 13° 40′. In this position of the grating the green of the second order was used and the magnifying power of the grating was a little greater than one-half, so that the coronal ring was distorted into an ellipse, in which the major axis was perpendicular to the length of the spectrum and parallel to the direction of daily motion.

The axis of the instrument having been adjusted to parallelism with the earth's axis, it remained only (i) to set the grating so that the coronal ring should appear in the middle of the field, and (ii) to focus the instrument. Neither of these operations could be done satisfactorily before the eclipse, that is, before the diminishing crescent of the sun made it possible to recognise the exact position of the spectrum in the field of view. Ten minutes before totality the dark lines were indistinctly visible in the spectrum, and a glance showed me that I had had an extraordinary stroke of good fortune in the rough setting of the grating, an operation which had been done by turning the grating till I thought the colour of the green was about right for the background of the magnesium lines. For the lines were only slightly displaced from the centre of the field, and the adjustment for the part of the spectrum required in the photograph was practically correct to a nicety. Accordingly no further adjustment was attempted. Two minutes before the beginning of totality the crescent was fine enough to show the dark lines in the spectrum very distinctly, a somewhat bewildering array of interlacing elliptical crescents, and the focussing was accomplished with ease. Mr. Henn then took charge of the instrument, and put a dark slide in position,

and adjusted the exposing shutter. I am very much indebted to him for his admirable precision in carrying out the programme of exposures.

The programme was carried out as follows :—

Three plates were exposed.

Plate X, 1. For the brightest chromospheric lines, at the beginning of totality—a short exposure, about $1\frac{1}{2}$ seconds.

This plate was to be exposed at the signal "Start," given by Professor Turner, and was to be closed between the time-keeper's calls "one" and "two."

It was actually exposed at the signal "Start," and closed at the time-keeper's call "three." The time-keeper found that the first beat of the metronome after "Start" came so soon that he did not call "one," but called the next beat "two" without calling "one" at all. The exposure was thus probably $2\frac{1}{2}$ seconds.

Plate X, 2. For the green coronal ring—a long exposure, about 40 seconds.

This plate was to be exposed as soon after Plate X, 1 as the change of plate holders would allow, and was to be closed at the call "fifty-five.

It was actually exposed at "nine" and closed at "fifty-five," and thus had an exposure of about 46 beats.

Plate X, 3. For the Fraunhofer lines immediately after the end of totality for comparison with any chromospheric lines that might appear on Plate X, 1.

This plate was to be exposed when I gave the signal "Now," and was to be closed 1 second later.

It was actually exposed at "seventy-one," and closed at "seventy-two."

*Results.*—The Plates X, 1 and X, 2 show faint images, but have not been examined carefully yet; a cursory examination shows that (*a*) only a single chromospheric line appears on X, 1; and (*b*) continuous spectrum appears on X, 2, but no *marked* coronal ring is discernible.

Plate X, 3 is a strong spectrum, showing the curved Fraunhofer lines between wave-lengths 5050 and 5460; the linear dispersion on the plate is, roughly speaking, 5 tenth-metres per millimetre.

*Remarks.*—In an eclipse with longer duration of totality, the procedure here described should give good results for the green coronal ring. The plates used were Edwards's Isochromatic Snapshot plates. It should be remembered that the effective aperture of the camera, viz., a little less than F/17, was rather dangerously small.

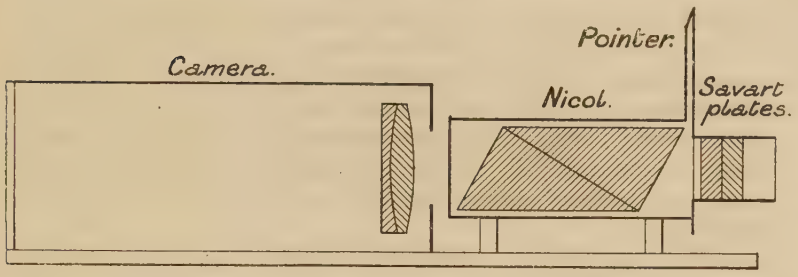
§ 26. *The Polariscopic Camera (Savart Plates and Nicol Prism).*

The glimpses of the corona that I was fortunate enough to get in India in 1898 through a small Savart polariscope convinced me that that instrument, if properly used, would give just the information that is wanted to decide some of the perplexing points that still survive in the spectroscopic and polariscopic study of the corona. The chief objection is that the phenomena are far too complicated to study by eye observations in the short time at one's disposal in an eclipse. Here is a case in which photographic methods should certainly be adopted if possible. Shortly after my return from India in 1898 I made some experiments to test the feasibility of photographing Savart's bands, and met with such promising success that no doubt was left in my mind that a photographic record of the distribution of Savart bands over the corona would give good results in supplementing the work which Professor Turner has in recent eclipses been carrying out in studying the polariscopic phenomena of the corona. Accordingly when I was asked to take part in the observations of the eclipse at Algiers, it seemed well to make arrangements to prepare a polariscopic camera.

Professor J. J. Thomson very kindly put two large Nicol prisms at my disposal. The aperture of these prisms is $1\frac{5}{8}$ inches. It was thus possible to use a lens of a focal length of about 3 feet, if suitable Savart plates could be found. On making the necessary calculations I found that the plates would have to be 15 mm. thick, cut in quartz at 45° to the axis of the crystal. A pair of such plates would give bands of the desired closeness, viz., about 10′ apart, instead of the usual 1° or 1° 30′. Fortunately Mr. Hilger was able to cut a slab, from the sloping top of a quartz crystal that I had in my possession, large enough to make two plates, each 14 mm. thick, of circular section, and with a diameter of 39 mm. ($1\frac{1}{2}$ inches). The whole slab was worked and polished with plane parallel surfaces, so as to secure equality of thickness, and was then cut into two parts, which were combined in the usual manner.

The figure shows diagrammatically the arrangement of the camera with the Savart plates and Nicol prism in front. The lens was a $3\frac{1}{2}$-inch lens of focal length 40 inches. The aperture was reduced to $1\frac{1}{2}$ inches, or approximately F/27 for central pencils. The Savart plates were fixed to the Nicol prism so that the bands were parallel to the plane of polarisation of the light transmitted by the Nicol. The whole system was arranged so that it could be rotated on its axis into any desired position, and a pointer was provided so that the position could be read off a large circle.

In discussing with Professor Turner the arrangements for the various items in the programme of observations to be carried out, he




very kindly suggested that the parts of this apparatus should be put into one of the compartments of the "double tube" alongside of the other polariscopic apparatus which he had himself arranged. I fell in with this suggestion very gladly, and the parts were taken to Algiers to be fitted there. It required very careful arrangement to get the two lots of apparatus into the tube, but in the end it was successfully accomplished, and Professor Turner made the exposures for the Savart camera simultaneously with those for his own polariscopic and other cameras. The pictures obtained with the Savart camera are on the same plates with the pictures obtained with Professor Turner's double image polariscopic camera.

The general procedure with the Savart camera was to be as follows:—The Savart and Nicol were to be rotated until the bands due to the plane polarisation of the sky in front of the corona were extinguished, and photographs of the corona were to be taken. But it was not possible to look through the camera itself in order to make the adjustment "to extinction," for this would have interrupted the exposures for all the other instruments in Professor Turner's charge. Accordingly a subsidiary Savart polariscope was provided, which I may call the visual Savart to distinguish it from the camera Savart. The visual Savart was set up in my hut, with pointer and graduated circle attached, and the zero and numbering of the scale were adjusted so that the readings corresponded with those of the camera Savart, account being taken of the fact that the sky was seen in the camera by reflection from the cœlostat.

The programme of exposures was as follows:—

1 second, 5 seconds, 20 seconds, 5 seconds, 1 second.

The first two were made with an arbitrary setting of the Savart, and the setting chosen was approximately that which would correspond to extinction of bands due to vertical polarisation. Meanwhile I had determined the plane of polarisation of the sky in front of the corona by observations with the visual Savart, made immediately after the exposures with the four-prism spectroscope were so far completed that the long exposure for the corona spectrum was begun, viz., 6 seconds

after the signal "Start." Mr. Potter, standing by me, received the reading resulting from my observations, and carried it to Professor Turner's hut, and Major Kingsley Foster adjusted the large Savart to the corresponding reading, and the third exposure was begun.

The camera Savart was left with the pointer at 10° for the rest of totality, no attempt being made to test the permanence in the position of the plane of polarisation of the sky as the total phase of the eclipse passed over.

*Results.*—The resulting photographs show strong bands over the corona. A cursory examination discloses the following results :—

No. 1. 1 second. Coronal extensions discernible as far as 10′ or 11′ from the limb.

No atmospheric bands visible, but obvious bands over the corona.

No. 2. 5 seconds. Coronal extensions as far as 35′ from the limb.

The planet Mercury appears on the plate.

Atmospheric bands are visible, very faint, on the following side of the sun, extending 4° 40′ from the limb, but are not visible on the preceding side near Mercury.

No. 3. 20 seconds. Coronal extensions 63′ in N*p* streamer.
„ „ „ „ 52′ in S*p* streamer.
„ „ „ „ 70′ in N*f* streamer.

Mercury very strong.

Atmospheric bands visible to the edge of the plate on both sides. Strong bands over the corona.

No. 4. 5 seconds. Coronal extensions 35′ from the limb.

No atmospheric bands visible on either side.

Nos. 5 and 6. Not examined.

The existence of the image of Mercury on the plates will be of great value in determining orientation in the polariscopic phenomena as well as in the corona.

The strong bands over the corona indicate that a considerable portion of the light is polarised. There are irregularities in the bands which seem likely to afford interesting study just in the way that was anticipated.

The atmospheric bands faintly visible on the plates are almost certainly due to imperfect adjustment of the Savart to extinction, arising from zero errors, &c.; they might be due to a change in the position of the plane of polarisation of the sky after the initial setting of the Savart. In any case they are very feeble, and it is clear that it would be well, if ever the experiments are repeated, to *aim* at imperfect adjustment

so that the atmospheric bands may be in opposite phase—*i.e.*, with black central band—to the coronal bands.

By a very fortunate accident just such an imperfection has arisen in the case of the plate No. 3, for the bright bands on the corona fall on dark atmospheric bands. It might be that the curvature of Savart's bands, which theoretically exists, misleads one ; but a tolerably careful examination of the faint bands shows them to be sensibly straight in the limited field dealt with, and the antagonism of the bands leaves no possible doubt that the bands seen on the corona are due to the polarisation of the corona.

It is difficult to reconcile the marked polarisation evidenced in this investigation with the absence of Fraunhofer lines in the spectrum of the corona.

Across the dark moon no atmospheric bands are discernible, and there appears to be no doubt that photographically the dark moon is darker than the sky. These are points that need explanation. An investigation of the real facts would be difficult, but none the less interesting ; for the idea suggested by much of the evidence along different lines is that some of the light which is usually attributed to the sky may come from beyond the moon. For instance, is a milky sky on a moonless night simply the result of starlight scattered by the processes producing scintillation, or are other causes at work ?

## § 27. *Atmospheric Polarisation.*

Preparations had been made that a systematic survey of the polarisation of the sky should be undertaken during the eclipse, with a view to determining the plane of polarisation in various quarters of the sky, a more precise knowledge of the general distribution of polarisation being needed for the explanation of some of the anomalies that appear to have been observed with respect to the atmospheric effects in previous eclipses.

Nine Savart polariscopes were mounted in similar turning tubes, provided with pointers and graduated circles, and attached to wooden stands. The stands were arranged so that each carried two polariscopes ; one pointed to the horizon, the other to a point 30° above the horizon. The four stands were fixed on the top of a tall box on the balcony of the equatorial coudé which M. Trépied had kindly put at our disposal. The polariscopes were directed towards the four quarters of the sky, N.E., N.W., S.W., and S.E. During the eclipse the sun was at an altitude of 30°, and only a few degrees north of west ; thus the polariscopes were directed to points nearly symmetrically disposed with regard to the sun. All the Savart plates were fixed relatively to the Nicol prisms, so that the bands were parallel to the plane of polarisation of the light transmitted by the Nicols.

The ninth Savart polariscope was mounted in a turning tube with pointer and circle complete, on a board which was screwed to an inclined block on the western doorpost of the hut which contained my spectroscopic apparatus. It was pointed towards the corona, and was in fact the visual Savart used by myself in the way described in the previous section (p. 363) for determining the position of the plane of polarisation of the light from the sky in the immediate neighbourhood of the corona, so that the camera Savart could be adjusted accordingly. The polariscope had been left in position with the bands horizontal and the pointer at 90°. Six seconds after the beginning of totality I left the spectroscope and looked through the polariscope. The eclipsed sun was slightly (perhaps 5°) to the north of the centre of the field of the Savart. The bands were seen fairly strong over the whole field of view, the central band being black. The Savart was then turned counter-clockwise, until the bands were extinguished. The reading was found to be 9° on the scale arranged to correspond with that on the large Savart in Professor Turner's hut. This reading showed that the plane of polarisation of the sky in front of the corona was inclined at an angle 4° to the vertical read counter-clockwise from the vertex. (There is possibly a zero error; it has not yet been determined.) When the atmospheric bands were extinguished faint traces of bands were seen over the corona, but much less strong than in the Indian eclipse.

I examined the polarisation of the sky in the zenith about 10 seconds after the end of totality, and found that the plane of polarisation passed through the sun.

Mrs. Newall undertook the charge of the eight other polariscopes, which were arranged as described above, and her programme for the eclipse was to turn each instrument, so that the Savart bands disappeared, paying attention to the direction of turning as follows:— If the band system had a white central band the polariscope was to be turned clockwise. If the system had a black central band it was to be turned counter-clockwise. The instruments were then to be left untouched, and the positions of the pointers were to be written down at leisure after the eclipse. Mrs. Newall devoted herself very diligently to setting the instruments under very varied conditions on the days preceding the eclipse, and so expert did she become that she was able to make the necessary settings of all eight polariscopes in about 42 seconds. If the polarisation was weak, about 50 seconds were needed. In the following table, taken at random from her notebook, the figures in the upper line are the readings of the pointers of the various polariscopes when the settings were made in a leisurely manner; those in the lower line are the readings when the settings were made "racing." "Hor." refers to the horizontal polariscope; "30°" to that which points upwards:—

| S.E. | | N.E. | | N.W. | | S.W. | | |
|---|---|---|---|---|---|---|---|---|
| Hor. | 30° | Hor. | 30° | Hor. | 30° | Hor. | 30° | |
| 106° | 74 | 168° | 178 | 170° | 121 | 114° | 136 | Leisurely. |
| 104 | 74 | 164 | 176 | 164 | 122 | 116 | 135 | Racing. |

The following readings show that in a leisurely setting the observation of extinction of the bands is satisfactory.

1900. May 24. Ten settings for extinction of bands in the middle of the field—16°, 15°, 16°, 12°, 16°, 17°, 16°, 17°, 17°, 16°. Mean 15°·8. It is thus clear that the "racing" settings give results of about the same order of accuracy as the leisurely ones.

In the eclipse itself, the observations were made on the balcony of the equatorial coudé, and unfortunately, on account of other noises, the signal, "Stand by," announcing that the beginning of totality was approaching, was not heard by Mrs. Newall, who was standing in the doorway of the balcony with a view of protecting her eyes from the sunlight till the last moment. Nearly half of the duration of totality had passed before she came into the open, and heard the twenty-eighth beat of the metronome being called. Going at once to the polariscopes she began to adjust them; she had set four of them "to extinction," and had nearly completed the setting of the fifth, when sunlight reappeared. With regard to the last observation, Mrs. Newall noted an interesting point. She had nearly completed the setting to extinction when the bands suddenly became bright again, with black centre, and she turned the polariscope counter-clockwise, from somewhere near the reading 20°, and had nearly set again to extinction before realising that totality was over. The reading of the polariscope was then found to be 345°.

The actual circle readings recorded immediately after the eclipse were as follows, and it was noted that the bands were very faint:—

| S.E. | | N.E. | | N.W. | | S.W. |
|---|---|---|---|---|---|---|
| Hor. | 30°. | Hor. | 30°. | Hor. | 30° | |
| 105°·0 | 94°·1 | 324°·8 | 340° | ?20° ± | | |

[345° after return of sunlight.]

These require small corrections for the index errors, which can only be determined after the instruments return from Algiers, but it may be provisionally stated that the angles made by the plane of polarisation with the vertical, read from the vertex clockwise, are as follows:—

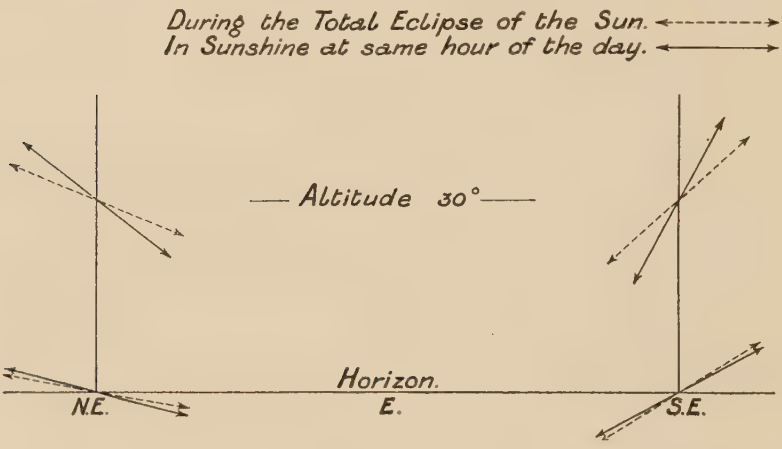
| S.E. | | N.E. | | N.W. | | W. |
|---|---|---|---|---|---|---|
| Hor. | 30°. | Hor. | 30°. | Hor. | 30°. | Over corona. |
| 60° | 49° | 280° | 295° | ?305° ± | | 356° |

[From my own observations.]

Comparison with the observations secured on other days at about the same time of day as the eclipse, viz., 4.30, may be summarised graphically as in the accompanying figure :—

Polarisation of the Sky. Algiers, 1900, May 26–28.

Plane of Polarisation.




The results are of considerable interest in their bearing on the well-known peculiarities in the phenomena of the polarisation of the sky in the neighbourhood of "neutral points."

It is a great satisfaction to be able to record these observations, for though they are incomplete, yet they were successfully carried out in spite of circumstances which would have upset many a practised observer; and the regret is all the greater that Mrs. Newall had to pay such a forfeit for her resolution, for she did not get more than a glimpse of the eclipse.

Of the nine Savart polariscopes used in these observations, four were lent to me by the Council of the Royal Astronomical Society, and three by Professor Lewis, through Mr. A. Hutchinson, of Pembroke College, Cambridge, who had arranged to come to Algiers, and had volunteered assistance in the observations recorded in Section 25 of this Report, but was unfortunately prevented at the last moment, by illness, from coming.

§ 28. *General Observations.*

The general darkness during totality was about the same as in India.

The dark moon did not appear so strikingly coal black in Algiers as it did in India. This is curious when considered in connection with the fact that the polarisation of the sky in front of the corona was much stronger in India than in Algiers.

Round the limb the brightness appeared relatively much greater in Algiers than in India. The breadth of the bright ring was estimated as 2′ to 3′; the decrease in brightness along the radius was very abrupt at this distance from the limb; at 4′ or 5′ from the limb a lower level of brightness was reached and thence outwards along the equatorial streamers the decrease in brightness was small up to points about 2° from the centre.

My impression of the streamers, recalled from a very vivid memory of the picture in my mind, is that the double streamer on the preceding side of the sun certainly extended beyond Mercury, and there was a similar extension on the following side. The latter extended for some distance as a broad streamer with nearly parallel edges.

I used a telescope of $3\frac{1}{2}$ inches aperture and of 29 inches focal length for viewing the corona direct. The instrument was merely clamped to the walls of the hut. I was able to focus the instrument carefully, and devoted some moments to examining the corona immediately outside the large prominence in the *Sp* quadrant. The prominence appeared double, one side having the form of a tapering column projecting radially from the limb, and the other appearing in cloud-like floating forms, both parts being of a wonderful rose colour. In the corona I was disappointed to find no striking signs of arches over the prominence. The only fine structure visible in the corona were a few interlacing wisps crossing one another, presumably in the part where the two streamers on the preceding side of the sun crossed one another in diverging from one another.

The shout that is stated to have risen from the Arabs in Algiers was heard by me as I exposed the plate for the spectrum of the corona, that is, as Mr. Wyles called "six." Algiers lies just a little more than a mile in a direct line from the Observatory. It seems probable that the shout was uttered at the same instant as Professor Turner's signal "Start," and announced that the totality had begun at Algiers.

"Solar Eclipse of May 28, 1900. Preliminary Report of the Expedition to the South Limit of Totality to obtain Photographs of the Flash Spectrum in High Solar Latitudes." By J. Evershed. Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received July 16, 1900.

This expedition was one of those organised by the Joint Permanent Eclipse Committee of the Royal Society and the Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee.

The following were the principal objects which I had in view in arranging the expedition:—

To obtain a long series of photographs of the chromosphere and flash spectrum, including regions of the sun's surface in mid-latitudes, and near one of the poles.

The photographs to be obtained with a long focus prismatic camera on a large scale, in order to be able to discriminate clearly between high levels and low levels in the chromosphere.

The photographs to include as much as possible of the ultra-violet region of the spectrum, for the purpose of verifying the results obtained with a smaller instrument in 1898, and to give more accurate values of the wave-lengths determined from those results.

This report may be conveniently divided into the following four sections, viz.:—

1. Selection of observing station.
2. Instruments, methods of mounting, and general arrangement of camp.
3. Narrative of expedition, and observations made on the day of the eclipse.
4. Results.

### (1) *Selection of Observing Station.*

A consideration of the conditions under which the lowest layers of the chromosphere are presented during a total solar eclipse showed that a very great advantage would be gained by selecting a station situated near the limit of the zone of total eclipse, where the two internal contacts would be separated by a small angle on the sun's limb.

At such a station the motion of the moon relative to the sun is in a direction approximating to parallelism with a tangent to the sun's limb at the points of internal contact, the result being that the excessively shallow layer giving rise to the so-called "flash spectrum" is

occulted by the moon comparatively slowly. Much more time is therefore available for taking a series of photographs than is the case at stations near the central line of the eclipse, where the moon's motion is at right angles to the layer, and opportunities for obtaining photographs of the very lowest strata are reduced to a fraction of a second only at each internal contact.

I decided therefore to choose some point situated well within the zone of total eclipse, but so far from the central line that the two internal contacts would be separated by an angle of about 39° on the sun's limb. This would give a duration of totality equal to one-third that at the nearest point on the central line; and the time available for photographing the flash spectrum would not be less than 30 seconds. At mid-eclipse the moon's limb would overlap the photosphere about 1″, so that even at that time the flash spectrum layer would not be entirely hidden.

Under these circumstances, also, one of the contacts would take place at, or very near to, one of the poles of the sun, the other being in latitude 51°. A succession of photographs taken during totality would therefore give a series of images of the flash spectrum ranging from solar latitude 51° to the pole.

In selecting the most suitable station, dryness of climate was considered to be the most important factor for securing extension of the spectra in the ultra violet; I therefore selected Algeria in preference to Spain, although the altitude of the sun would be less in the former country.

The best position in Algeria for realising the greatest solar altitude was a point on the coast west of Algiers, and on the southern border of the eclipse track. This region was therefore decided upon at the outset, and in order to realise the favourable conditions mentioned above, two stations were selected provisionally beforehand, and for these Dr. Downing kindly computed for me the durations of totality according to the data used by the Nautical Almanac Office.

The first station, near to the village of Zeralda, was found by him to have a duration of 45 seconds, *i.e.*, more than one-half the central line duration. The other station, three miles further south, and near to Maelma, was computed to have a duration of 29·5 seconds with a possible error of ± 10 seconds.

As the required conditions would, apparently, be very nearly fulfilled at the latter station, I decided to place my camp either at that precise spot, or at some point situated on a line passing through it, and parallel to the direction of the shadow track in that region.

The actual station eventually chosen was 6·5 kilometres distant from the station near Maelma, in a direction bearing West 25° North. Here it was estimated that totality would last 30 seconds. Unfortunately, as the event proved, the value of the diameter of the moon adopted by

our Nautical Almanac Office is too large, and the limits of error given above were very misleading. Instead of a duration of 30 seconds, the eclipse at my station was never quite total.

(2) *Instruments, Methods of Mounting, and General Arrangement of Camp.*

It was my intention originally to take out a fine 18-inch silver-on-glass concave mirror made by the brothers Henri, which was given to me by the late Mr. Ranyard. This mirror, having a focal length of 117 inches, would have given images on a scale of 1·08 inch to the sun's diameter

Many experiments were made with this mirror to determine the amount of aberration produced on star images at considerable distances from the axis, and with various apertures. It was found that when the ratio of aperture to focal length did not exceed 1/15, good images were obtained 4° from the normal axis, the aberration being very slight.

As this would admit of a very wide range of spectrum being photographed with good definition throughout, I decided to adapt my large reflecting telescope for eclipse work. Owing, however, to the difficulty of obtaining a prism of large angle and not less than 6 inches aperture, I had, most unfortunately, to abandon this scheme and construct a much smaller apparatus.

Through the kindness of Dr. Rambaut I eventually obtained a fine 4-inch prism of light flint glass and 45 degrees angle. This prism, which was generously placed at my disposal by Sir Howard Grubb, proved most efficient for the work, although I was unable to utilise the full aperture.

Three spectrographs were finally made: a reflecting prismatic camera of 3 inches aperture and 74 inches focus, an ordinary prismatic camera of 2 inches aperture and 47 inches focus, and a quartz prismatic camera of 1 inch aperture and 24 inches focus. These were mounted together inside an observing hut, and were supplied with light from a 12-inch cœlostat.

*The Reflecting Prismatic Camera.*

This was an ordinary reflecting telescope with a mirror of 9 inches aperture and 74 inches focus. It was fitted with a strong wooden tube, adapted for carrying two large prisms near the upper end. The prisms used were the 4-inch 45-degree prism, lent me by Sir Howard Grubb, and a 3-inch 60-degree prism lent me by Dr. Common. These were mounted eccentrically within the tube, in such a manner that the incident light, after passing through the prisms, made an angle of about $1\frac{1}{2}^\circ$ with the normal axis of the mirror. After reflection from the mirror the rays returned over the upper surface of the 60-degree prism, and came to focus about an inch outside the end of the tube

The end of the tube was closed by a block of wood having an aperture 8 inches long by 3 inches wide, a little above the middle. Outside this a long slide was arranged, at right angles to the telescope, and bolted at the upper end to two stay rods attached to the telescope near the mirror.

A plate holder, 3 feet long by 10 inches wide, taking two plates $8\frac{1}{2}$ inches square and four plates $8\frac{1}{2}$ by $4\frac{1}{4}$ inches, was arranged to move along the slide by means of rackwork and a pinion wheel. One revolution of the pinion moved the plates 2·13 inches, whereby four images could be obtained on the square plates and two on each of the narrow ones; the sixteen images all being equal distances apart and symmetrically placed on the plates. The revolutions of the pinion wheel were controlled by a spring catch acting on the crank handle, and holding it firmly in position after each revolution.

The whole slide, carrying the plate holder, &c., was attached to the telescope in such a way that the distance of the plates from the mirror could be varied a small amount for focussing.

The tube of the instrument was firmly bolted down to the sloping side of a solid pier of stone and cement, built up within the observing hut near the north end. It was adjusted so that the plane of dispersion of the prisms was in a meridian passing through the cœlostat, and inclined to the prime meridian 68° (the hour angle of the sun at mid-eclipse). The dispersion was therefore in a north and south direction. The internal contacts were computed to occur near to the south point of the sun, and on either side of it. The centre of the flash spectrum arcs was therefore midway between the edges of the spectrum in the photographs obtained at mid-eclipse.

### *The 2-inch Prismatic Camera.*

This instrument was the same which I employed successfully at the Indian eclipse in 1898, excepting that it was fitted with a specially corrected lens of 47 inches focus instead of the visual objective previously used. The images were therefore on a somewhat larger scale, and larger plates were used.

The sliding plate holder, constructed on the same lines as the larger instrument already described, was made to hold three plates, $6\frac{1}{2}$ by $4\frac{1}{4}$ inches, placed lengthwise in the holder; and the crank handle moving the slide was arranged to stop at each half revolution, moving the plates 1·12 inches between each exposure.

The two 60° prisms of this instrument are made of specially selected crown glass, and are exceptionally transparent for ultra-violet rays.

The total deviation of the two prisms being approximately equal to that of the reflecting spectrograph (about 80°) the tubes of the two in-

struments were arranged nearly parallel, the 2-inch spectrograph being screwed to the side of the reflector with its aperture alongside that of the latter. The camera end with the sliding plate holder was at the lower end.

*The Quartz Prismatic Camera.*

This was rigged up while in camp, as it was found that a small portion of the cœlostat mirror was available to supply light. It consists of two double quartz prisms of 60° and 40° angle respectively, each prism having $1\frac{1}{4}$-inch square faces; and a single quartz lens of 24 inches focus. It was screwed on the top of the 2-inch spectrograph, with its aperture just within the elliptical beam of light from the cœlostat.

My brother arranged a very convenient exposing shutter, which he was to open near mid-eclipse for a single exposure of 10 seconds.

*Methods of Focussing.*—All three spectrographs were approximately focussed by taking a series of photographs of the spectrum of Venus. Having determined the focus of the reflecting prismatic camera in this way within very narrow limits, I used this instrument as a collimator for the 2-inch spectrograph, removing the large prisms, and adjusting a slit in the position occupied by the plates when photographing Venus. The 2-inch instrument was attached to the wall of the hut, with its aperture inside the tube of the reflector, and directed towards the mirror. With the north door of the hut widely open, the slit was illumined by light from the sky, and a series of photographs was obtained of the Fraunhofer spectrum.

For some reason the focus was not so sharply defined, and the definition of the lines was not so good as in photographs I had obtained by the same method before leaving England.

A third method was therefore tried. After having adjusted the 2-inch spectrograph in its correct place, photographs were obtained of the sun itself on Sandell triple plates; the focus being determined by the images which were most sharply defined along the edges.

A final method, which was adopted for the two larger instruments, was to adjust the focus visually during the eclipse itself, using the Fraunhofer lines, which become sharply defined shortly before totality

*Programme of Exposures.*—The two larger prismatic cameras were each to have sixteen exposures made simultaneously, by removing a plate of aluminium from the common aperture of the two instruments. The first, second, fifteenth, and sixteenth exposure were to be of about 1 second duration each, and the remaining exposures of 2 seconds duration, excepting the exposure nearest to mid-eclipse, which was to have 10 seconds.

The quartz prismatic camera was to be exposed near mid-eclipse also for 10 seconds.

These relatively long exposures were designed to secure density in the ultra violet, at the risk of over-exposing in the region near G.

Having ascertained by rehearsing that the time required for exposing all the plates would be about 90 seconds, I arranged that the first exposure should be timed at 45 seconds before the computed time of mid-eclipse The succeeding exposures were to follow each other at the shortest intervals, turning the handles deliberately, and allowing ample time for shake to subside before each exposure.

I was to use my discretion to some extent in making the long exposure at mid-eclipse, but otherwise I intended to be guided solely by the chronometer.

The exposures were to be made by myself, standing at the north door of the hut and facing the large spectrograph. I used my left hand to work the exposing shutter, and my right to rack the plates forward in the slide.

My brother, sitting on his bed in the hut, was to move the plates of the 2-inch spectrograph, turning the handle half a revolution after each exposure. He was also to expose the quartz spectrograph at a signal from me.

*The Cœlostat.*

A 12-inch cœlostat was used to supply light to the three spectrographs in the hut. It was placed about 6 feet from the north-east corner of the hut, and was arranged to reflect the sun in a meridional plane; the angle between the incident and reflected beam being in this case a minimum, viz., declination of sun × 2. The reflected beam was in a direction W. 30° S., and was directed upward at an angle of $3\frac{1}{2}^{\circ}$ with the horizontal.

The instrument was mounted on a steel plate fixed on the top of a masonry pier, and about 3 feet from the ground. The plate had a straight channel cut in it just wide enough to take the ends of two of the four levelling screws, the other two resting on the planed surface of the plate.

With the plate placed approximately level and the channel approximately north and south, the whole instrument could be shifted bodily north or south without disturbing the adjustments of the axis in altitude and azimuth. In this way the adjustment of the beam of light with respect to the apertures of the three spectrographs was very easily managed, and the cœlostat could be shifted about to suit the varying declination of the sun on occasions, previous to the eclipse, when it was desired to observe the spectrum and adjust the spectrographs.

The cœlostat was provided with slow motion independent of the driving gear, and this was controlled from inside the hut by means of a rod, 8 feet long, which my brother laboriously cut from a 3-inch plank.

The driving clock was bolted down to the north end of the cœlostat pier. It was driven by a weight suspended from a large tripod erected near.

*The 3¼-inch Telescope.*

In addition to the photographic instruments I had a 3¼-inch equatorial telescope, and a high dispersion solar spectroscope. The telescope was mounted on a packing case outside the hut, and was useful in a variety of ways. With the spectroscope attached it was used for the observation of solar prominences on the day of the eclipse, and on several other occasions.

*The Observing Hut.*

This was a rectangular wooden shed, the sides enclosing a space 14 by 9 feet and 6 feet high. The sloping roof was covered with boards up to about 1 foot from the centre beam. A large sheet of canvas was stretched above the boards, leaving an air space between: this allowed of the free circulation of air between the canvas and the wood, and was designed to prevent the interior from becoming unbearably hot during the day.

This arrangement, however, was anything but water-tight, as we found to our cost during a spell of bad weather. We subsequently procured a large rick cover, which was tied securely over the canvas and down to the ground on the weather side of the hut.

This hut was designed by my brother for the accommodation of the somewhat unwieldy reflecting spectrograph and two camp beds. The frame was constructed by him before leaving England.

The accompanying ground plan shows the general arrangement of the camp.

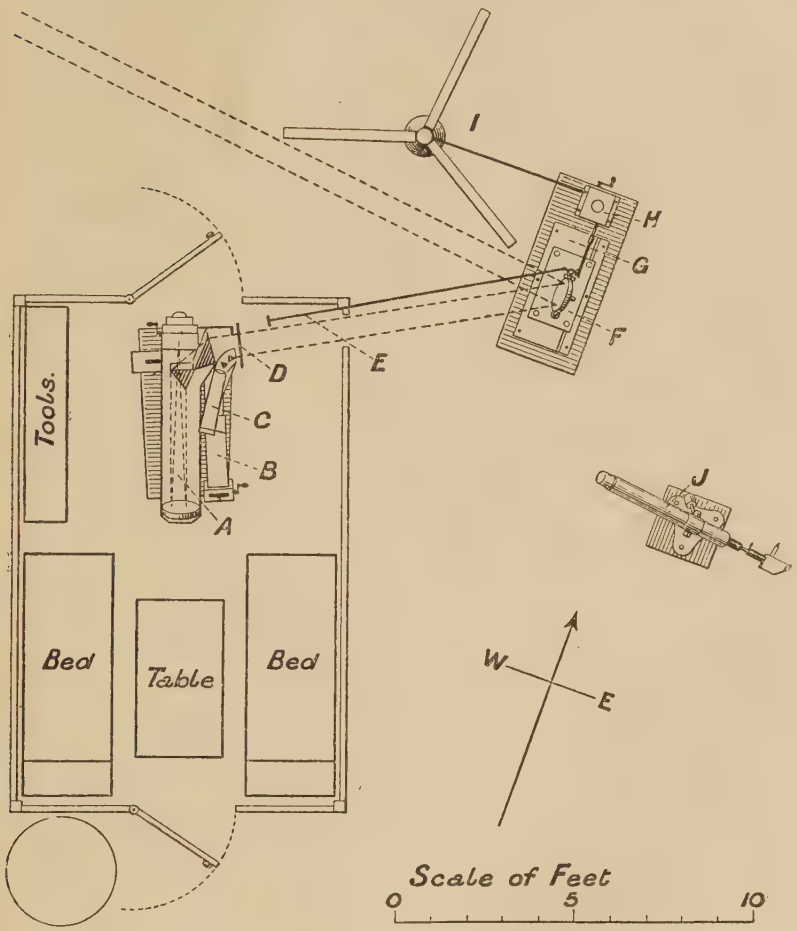
(3) *Narrative of Expedition and Observations made on the Day of the Eclipse.*

The expedition, consisting of my brother (Mr. Harry Evershed) and myself, left England on April 30th, and travelling *via* Paris and Marseilles arrived at Algiers on May 3rd.

At Algiers we received every attention and assistance from the British Consul-General, Mr. Hay Newton, to whom our acknowledgments are due. He procured for us a letter from the Préfecture to the Mayor of Maelma, ordering the latter to assist us in every possible way in selecting a site for our camp.

We also received assistance and advice from M. Trépied, of the Algiers Observatory, who very kindly called at our hotel and discussed with us our plan of operations.

PLAN OF OBSERVING STATION, MAZAFRAN CAMP.




A. Reflecting spectrograph.
B. 2-inch spectrograph.
C. Quartz spectrograph.
D. Exposing shutter.
E. Cœlostat slow-motion handle.
F. Cœlostat.
G. Planed steel plate with channel.
H. Driving clock.
I. Tripod for weight.
J. 3-inch telescope and spectroscope.

Having obtained letters of introduction to some landowners in the district we intended to occupy, we went at once to the village of Zeralda, about 20 miles west from Algiers, and making this our head-quarters for a few days we explored the neighbouring country.

The people to whom my brother had letters received us with the greatest civility, and we desire to mention in particular M. Buloff,

administrator of the estate of the Comte de Perigord, and formerly Professor at Stonyhurst. This gentleman was much interested in our mission, and we are practically indebted to him for giving us a letter to a colonist, M. Alvado, upon whose farm near the sea coast we eventually found an excellent site for our camp.

It was evident at the outset that the wild hilly region near the village of Maelma would be more difficult of access than the country further west near the coast. Maelma itself we found to be poverty-stricken and unpromising. The mayor, whom we found in his mairie busy with the coming elections, was obliging enough to *visé* our document from the Préfecture; or rather he got his secretary to do so, being unable himself, apparently, to read or write. Having had our letter duly *viséd* we abandoned Maelma, and proceeded to the Mazafran River, near the coast, to conclude negotiations already entered into with Alvado.

These presented no difficulty, for M. Alvado was "un homme très brave," and offered us his whole territory, vineyards or cornfields, for our camping-ground. We were, however, limited in our choice to a line bearing West and 24½ degrees North from Maelma, in order to secure the same duration of totality as had been computed for that place.

The position finally chosen was near to the mouth of the Mazafran River on the east side, and about 1 kilometre from the sea.

The position of the Mazafran bridge, about 400 metres distant, was ascertained from a recent survey to be

| | | | |
|---|---|---|---|
| North latitude ..... | 36° | 41′ | 35″ |
| East longitude ..... | 2 | 48 | 30 |

The position of the camp, which my brother carefully determined by triangulation from the bridge, was as follows:—

| | | | |
|---|---|---|---|
| North latitude ..... | 36° | 41′ | 47″ |
| East longitude ..... | 2 | 48 | 41 |

It was 17 metres above sea-level, and 6·5 kilometres from the station near Maelma, in a direction bearing West 25° North.

As the direction of the shadow track in this region was ascertained to be 24° 39′ North of West, we concluded that the above position would be safe for a duration of 30 seconds of totality.

Having settled all preliminaries we returned to Algiers to arrange for the transport of the instruments. This was effected without difficulty by means of the light railway recently constructed from Algiers to the Mazafran.

On May 9th we returned to Alvado's farm, and the next day the work of erection was begun.

Our hut, which was to serve as sleeping and living room as well as observatory, we had ready for occupation the same evening.

During the fortnight preceding the eclipse, our time was fully occupied in erecting and adjusting the three spectrographs, cœlostat, and other instruments, and in taking trial photographs for determining focus. We also made daily observations of the sun with a sextant and artificial horizon for determining time, and checking the rate of a chronometer which we had hired for use in our camp. Being far from any telegraph station in direct communication with Algiers, we were obliged to depend entirely on observation for our time on the day of the eclipse. Working with instruments of very second-rate quality, my brother usually succeeded in determining local time within one or two seconds of error, taking the mean of a day's set of observations (usually employing the method of double altitudes).

During the whole time we were in camp, we were ably assisted by our host, M. Alvado, who took a most intelligent interest in all our operations, and was ever ready and at hand to help us in any and every difficulty with which we were confronted. We take this opportunity of expressing our high appreciation of his services, and esteem for his character, and that of his wife, Madame Alvado. The latter attended most assiduously to all our personal wants, and in this way furthered most materially the objects of the expedition.

*Observations made on the Day of the Eclipse.*

Between 6 and 7 A.M. on May 28th I observed in the spectroscope the position angles and approximate heights of all the prominences then visible on the sun's limb. The results were then written out in accordance with a previously arranged code, and sent on to Zeralda to be telegraphed to Mr. A. C. D. Crommelin, at Algiers, for the use of intending observers of the coronal structure near to prominences.

The following table gives the position angles and heights observed:—

| Position angle. | Solar latitude. | Approximate height Hα. |
|---|---|---|
| 64° | + 9° | 50″ |
| 119 | − 46 | 15 |
| 217 | − 36 | 115/130 |
| 236 | − 17 | 25 |
| 305 | + 52 | 20 |

The rest of the morning was devoted to final adjustments and rehearsals; cleaning all lenses and prisms, and in taking more photographs for focus in the 2-inch spectrograph. Soon after noon all slides were filled ready for the eclipse; and lastly, the 9-inch mirror and the cœlostat mirror were both dusted and carefully polished with rouge to remove all trace of tarnish.

Fifteen minutes before mid-eclipse the large spectrograph was slightly readjusted for focus by observing with a lens the spectrum image of the diminishing crescent. This was effected without any difficulty or uncertainty.

I then attempted to focus the 2-inch spectrograph in the same way, using the Fraunhofer lines near G, which were then rapidly becoming sharply defined. As the last determination made photographically appeared to be correct, I set it again to the same position.

Five minutes before mid-eclipse my brother wound up the cœlostat clock, and three minutes later I gave the order "Stand by."

The light waned rapidly, and I began the exposures at $4^h\ 16^m\ 58^s$. At $4^h\ 17^m\ 30^s$ I found it difficult to see the seconds hand of the chronometer, and a few seconds later I opened for the 10-second exposure, giving at the same time the signal to expose the quartz spectrograph. The absence of any sound from the shutter warned us that the latter had failed to act.

At $4^h\ 18^m$ I could again see the chronometer face clearly. I continued the exposures according to the programme, finishing the last at $4^h\ 18^m\ 18^s$.

A minute or two later, after removing all the plate holders from their slides, I observed the large prominences on the south-west limb in the spectroscope attached to the 3-inch telescope. They appeared, of course, exceedingly brilliant in the line H$\alpha$. Unfortunately, I was unable to make a critical examination of the spectrum, for at this time a crowd of sight-seers inundated the entire camp, and further observation for the time being was impossible.

Later, I observed the time of last contact with the spectroscope. This took place at

| | |
|---|---|
| $5^h\ 21^m\ 34^s$ | per clock. |
| $+58$ | assumed error of clock. |
| 5 22 32 | G.M.T. |

At this moment the moon's limb was seen as a black line projected on the chromosphere.

### (4) *Results.*

Notwithstanding the fact that my station was outside the zone of total eclipse,* the photographs show that there was quite half a minute

* From the descriptions given us immediately after the eclipse by M. Alvado and others who undertook to determine accurately the duration of totality, it appeared certain that the photosphere never wholly disappeared, a small point of sunlight remaining visible at the moment of mid-eclipse. The edge of the moon's shadow was, moreover, clearly seen traversing the sea and the sand dunes a short distance north of our camp, which escaped the shadow by a few hundred metres only.

available for obtaining good images of the flash spectrum. No. 9 spectrum, for instance, is one of the finest of the series, and shows about as many bright lines as the mid-eclipse photograph, yet it was exposed 15 seconds before mid-eclipse. Several other photographs taken earlier than No. 9 also show a large number of flash spectrum lines.

I think this result demonstrates the very great advantage gained at stations near the limit of total eclipse for studying this spectrum.

In cleaning the lens of the quartz spectrograph shortly before the eclipse, I unfortunately jammed the exposing shutter in such a way that it would not work at the critical time, and no photograph was obtained with this instrument.

Sixteen photographs were obtained with the 2-inch spectrograph, and sixteen with the reflecting spectrograph. The following table gives the approximate times of exposure, and the plates used in each instrument:—

| Exposure No. | Approximate times. | | Plates used. | |
|---|---|---|---|---|
| | Beginning. | Duration. | Reflecting spectrograph. | 2-inch spectrograph. |
| | h. m. s. | sec. | | |
| 1 | 4 16 58 | ½ | Sandell Triple | Sandell Perfect. |
| 2 | 17 5 | 1 | ,, ,, | ,, ,, |
| 3 | 10 | 2 | Sandell Perfect | ,, ,, |
| 4 | 14 | 2 | ,, ,, | ,, ,, |
| 5 | 18 | 2 | Edwards's Ordinary Medium | ,, ,, |
| 6 | 23 | 2 | ,, ,, | Imperial Ordinary (Backed) |
| 7 | 27 | 2 | ,, ,, | ,, ,, |
| 8 | 31 | 2 | ,, ,, | ,, ,, |
| 9 | 35 | 2 | ,, ,, | ,, ,, |
| 10 | 40 | 2 | ,, ,, | ,, ,, |
| 11 | 45 | 10 | ,, ,, | ,, ,, |
| 12 | 18 0 | 2 | ,, ,, | Sandell Triple. |
| 13 | 4 | 2 | Sandell Perfect | ,, ,, |
| 14 | 9 | 2 | ,, ,, | ,, ,, |
| 15 | 13 | ½ | Sandell Triple | ,, ,, |
| 16 | 17 | ½ | ,, ,, | ,, ,, |

The images obtained with the 2-inch spectrograph are not in good focus. They are very dense in the region near G, but correctly exposed in the ultra-violet. The spectra extend from λ 3350 to λ 5100. Apparently the maladjustment of focus has produced a linear distortion of the images; and at the edges of several of the spectra, where the direction of the distortion coincides with the direction of the bright

lines, the focus appears to be quite perfect through the whole length of the spectrum.

This suggests that the lens, which was a thin one, was under some strain in its cell, and it accounts for the difficulty experienced in finding the true focus.

In the mid-eclipse photograph (No. 11) the bright lines are fairly well defined at the extreme end of the spectrum, and they can be traced in this photograph to λ 3320. All the lines between λ 3340 and λ 3500 can be identified with those shown on the best plate obtained in 1898.

The following table gives the wave-lengths and identifications of these lines as determined for the spectrum obtained in India. In identifying the lines with the elements given in column 4, I received great assistance from Mr. L. E. Jewell, who also supplied me with a revised list of wave-length values for the solar lines given in column 5.

The intensities (column 2) are estimated as follows:—

Lines just visible but extremely faint ..... = 0
The strongest lines in the spectrum ..... = 10

| Wave-length (flash spectrum). | Intensity. | Character. | Element. | Wave-length, Rowland (solar spectrum). |
|---|---|---|---|---|
| 3326± | 2 | Wave-lengths roughly estimated on photograph No. 11 of 1900. | | |
| 3330± | 2 | | | |
| 3333± | 1 | | | |
| 3335± | 2 | | | |
| 3340·0 | 1½ | First line on photograph | Cr? *Ti* | 3340·490 |
| 3342·3 | 2 | No. 3 of 1898 ..... | Ti | 42·012 |
| 3347·0 | 0 | (One measure only)..... | Ti | 46·882 |
| 3349·4 | 4 | Long ..... | Ti | 49·558 |
| 3354·0 | 2 | Faintly extended ..... | Sc | 53·875 |
| 3358·5 | 2 | | Cr | 58·649 |
| 3361·4 | 3½ | Long ..... | Ti | 61·327 |
| 3368·3 | 3 | Long ..... | Cr | 68·193 |
| 3373·0 | 4 | Long ..... | Ti | 72·948 |
| 3380·4 | 3 | Short ..... | Ti | 80·424 |
| 3384·9 | 4 | Long ..... | Ti | 83·892 |
| 3388·1 | 3 | Long ..... | Ti | 87·988 |
| 3392·1 | 1½ | (One measure only)..... | Zr? | 92·109 |
| 3394·7 | 3 | Long ..... | Ti | 94·716 |
| 3399·3 | 1 | Short ..... | | |
| 3403·45 | 3 | Faintly extended ..... | Cr | 3403 404 |
| 3405·17 | 1 | Short ..... | Co? | 05·217 |
| 3407·32 | 1 | Short ..... | Fe? | 07·597 |
| 3408·97 | 3 | Long ..... | Cr | 08·911 |
| 3410·24 | 1 | Visible on south side only. | | |
| 3415·01 | 1 | Visible on south side only .. | Ni | 14·911 |
| 3421·42 | 3½ | Equal pair; long..... | Cr | 21·353 |
| 3422·94 | 3½ | | Cr | 22·892 |

| Wave-length (flash spectrum). | Intensity. | Character. | Element. | Wave-length, Rowland (solar spectrum). |
|---|---|---|---|---|
| 3425·46 | 0 | One measure only; very short. | | |
| 3426·97 | 0 | | | |
| 3428·73 | 0 | | | |
| 3430·61 | 1 | Short | Zr? | 3430·671 |
| 3433·54 | 4 | Long | *Cr*, Ni | 33·453, 33·715 |
| 3438·40 | 2 | Short | Zr? | 38·376 |
| 3440·93 | 3 | Faintly extended | Fe, Fe | 40·762, 41·155 |
| 3442·24 | 4 | Long | .. | 42·112 |
| 3444·39 | 3 | Faintly extended | Ti | 44·467 |
| 3446·34 | 2 | Ill-defined | Ni | 46·406 |
| 3452·86 | 2 | | Ni | 53·039 |
| 3456·55 | 2 | Ill-defined; short | Ti | 56·528 |
| 3458·58 | 1 | | Ni | 58·601 |
| 3460·53 | 3 | Long | Mn | 60·460 |
| 3461·68 | 2 | Faintly extended | Ti, Ni | 61·633, 61·801 |
| 3463·05 | 1 | Interrupted; very short | Co | 62·950 |
| 3464·32 | 1 | Visible on continuous spectrum only. | Sr? | 64·608 |
| 3465·87 | 2 | Very faintly extended | Co, Fe | 65·900, 66·015 |
| 3467·46 | 0 | | | |
| 3468·72 | 0 | .. .. .. | Fe | 68·821 |
| 3471·33 | 1 | Equal pair, short, and interrupted | | |
| 3472·58 | 1 | | Ni | 72·680 |
| 3474·28 | 3 | Long | Mn | 74·287 |
| 3475·67 | 2 | Short | Fe | 75·594 |
| 3477·26 | 3 | Long | Ti | 77·323 |
| 3479·48 | 1½ | Ill-defined; short | Zr? | 79·531 |
| 3481·20 | 1½ | | Zr? | 81·302 |
| 3483·08 | 3 | Long | Mn | 83·047 |
| 3488·85 | 3 | | Mn | 88·817 |
| 3491·16 | 3 | | Ti | 91·195 |
| 3493·22 | 2 | Ill-defined | *Ni*, Fe | 93·114, 93·618 |
| 3494·60 | 1 | Short. | | |
| 3496·17 | 3 | Long. | | |
| 3497·82 | 2 | Short. | | |
| 3499·14 | 0 | Interrupted. | | |
| 3500·45 | 1 | Short. | | |
| 3502·30 | 0 | (One measure only) | Co | 3502·394 |
| 3505·06 | 3½ | Long; equal pair | Ti | 05·036 |
| 3510·96 | 3½ | | Ti | 10·985 |

In column 4 the predominating element in a group is put in italics.

The sixteen images of the cusp and flash spectra obtained with the reflecting spectrograph are in good focus throughout.* Each spectrum

* The very strong chromosphere arcs, such as H and K, show a faint coma on the more refrangible side. This has since been traced to slight irregular refraction at the base of the 60° prism. The fault is, however, too slight to appreciably affect the definition of any but the strongest lines.

is 8 inches long, and extends from λ 350 to λ 510. The width corresponding to the sun's diameter is 0·68 inch.

The finer flash spectrum lines in many of the photographs are particularly well defined in the ultra-violet.

The first four photographs of the series are much over-exposed and fogged, and only the stronger chromosphere arcs are visible at the edge of the continuous spectrum. In the succeeding images, the sky illumination becoming much diminished, the bright lines show up clearly on a light background.

In No. 9 the flash spectrum is fully developed in a rift in the continuous spectrum. This rift extends from position angle 140° to 148°, and includes a region between 67° and 75° south latitude. The bright lines crossing the rift are beautifully defined throughout the spectrum, and in the ultra violet they can be traced nearly as far as the continuous spectrum. The Fraunhofer lines are well defined upon the continuous spectrum, where the latter has not been over-exposed, and the whole spectrum in the ultra-violet is a mixture of bright and dark lines.

Accurate determinations of wave-length will result from the measurement of this negative.

No. 11. This was exposed for 10 seconds at the greatest phase of the eclipse. The continuous spectrum is broken up into five narrow bands, and the flash spectrum lines form long arcs crossing the bands. Most of these arcs extend over nearly 80° of the limb, and cover the entire south polar region, from latitude −75° on the east side to latitude −28° on the west.

The bright lines on this negative are more strongly impressed than on any of the others, and they can be clearly traced up to the end of the continuous spectrum at λ 350. The dark lines of the Fraunhofer spectrum are still traceable on the narrow strips of continuous spectrum.

This negative will give good wave-length determinations for all the finer lines between λ 350 and λ 510.

Good images of the flash spectrum are also impressed on photographs Nos. 10, 12, and 13.

*General Conclusions.*

(1) In its main features the flash spectrum at the south pole of the sun is the same as in low latitudes.

(2) No essential change is shown after an interval of four years; the spectra photographed by Shackleton, in 1896, and those obtained in 1898 and 1900, all appear to be identical so far as it has been possible to compare them.

(3) The flash spectrum, therefore, is probably as constant a feature of the solar surface as is the Fraunhofer spectrum.

With regard to instruments, the reflecting prismatic camera has proved to be a most efficient form of spectrograph for eclipse work.

The uniform focus over the entire range of spectrum, and the facility with which the adjustment for focus can be effected, are advantages which those who have worked with prismatic cameras will appreciate.

Another important advantage in the use of the reflector is the proximity of the exposing shutter to the plate holder, both of which can easily be controlled by one person. There is no signalling between the man at the plates and the man at the shutter.

There is again the advantage that there is no selective absorption of ultra-violet rays which occurs in lenses, and if the mirror is freshly polished there is no selective reflection for any of the rays which can be photographed.

In concluding, I have to acknowledge my great indebtedness to my brother for his untiring devotion to the interests of the expedition throughout. In all the negotiations necessary on arrival in the country he took a leading part, and was successful in obtaining the goodwill of every person with whom we came in contact.

The fine series of photographs which we obtained bear witness to his skill in carrying out, to the letter, the somewhat troublesome arrangements which I had planned for erecting and adjusting the instruments.

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"Preliminary Note on Observations of the Total Solar Eclipse of 1900 May 28, made at Santa Pola (Casa del Pleito), Spain." By RALPH COPELAND, Ph.D., F.R.A.S., F.R.S.E.—Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received October 1, 1900.

I had again the honour of being nominated one of the observers for the Joint Eclipse Committee, the station allotted to me being at Santa Pola, on the south-east coast of Spain.

On the 9th May I left Edinburgh, and sailed from Tilbury on the 11th in the Orient steamship "Oruba," accompanied by Mr. Thomas Heath, First Assistant at the Edinburgh Royal Observatory, who was going to Santa Pola to observe the eclipse on behalf of the Royal Society of Edinburgh.

My instrumental outfit had preceded me under the care of Mr. James McPherson, the experienced mechanician of our Edinburgh observatory. This outfit comprised the 40-foot horizontal telescope of 4-inch aperture previously used in India and Norway, together with a small Iceland spar and quartz prismatic camera, with an effective aperture of 1·8 inch.

At St. Pancras Station I had the pleasure of joining Sir Norman Lockyer and his party, who, like ourselves, were bound for Santa Pola.

Early on the 16th we reached Gibraltar, where we were met by another member of our Edinburgh party, Mr. Franklin-Adams, from Machrihanish, who had most thoughtfully arranged for the transfer of all our eclipse apparatus from the "Oruba" to H.M.S. "Theseus," which the Admiralty had generously placed at the disposal of the Joint Committee. We were most cordially welcomed on board the "Theseus" by Captain Tisdall, who introduced us to his officers, and assigned to us our most comfortable quarters.

The few days spent on board the "Theseus" passed most pleasantly. With the greatest interest we followed the various forms of drill, and were greatly struck by the promptitude and precision with which every order was carried out.

On landing at Santa Pola on the afternoon of the 17th we were received with the utmost courtesy by the Alcalde and other Spanish authorities, who at once assured us of all possible assistance in the furtherance of our work. The interchange of courtesies being over, we at once proceeded to the camp already laid out for Sir Norman Lockyer's party. Abundant space had been left for the installation of our apparatus, but on closer examination of the ground we found the subsoil too light and sandy to afford the firm foundation required by our heavy instruments. We had therefore to select another site. This we found in the upper part of the town, in a barley-field, from which the crop had been gathered a few days before. Here the solid rock, covered only by a thin layer of soil, afforded an ideal foundation for all our apparatus, while the neighbouring walls or houses protected the site from the prevailing winds without unduly obstructing the view.

To the south-east of the selected spot stood a large barn, which chanced to be vacant in consequence of a law suit, and was therefore called "La Casa del Pleito." This barn was allotted to us by the ever-obliging Alcalde, and gave the name to our station. It served in the threefold capacity of a store-place for our empty boxes, a photographic laboratory, and a most welcome retreat from the burning rays of the noonday sun.

While our instruments were being landed and carted up on the morning of the 18th, we commenced laying out and preparing the necessary foundations for them. In this, as in all our work, we were most efficiently helped by a detachment of junior officers and men from the "Theseus."

For the first few days there was a good deal of cloud, by night as well as by day, and it was only with difficulty that the exact observations requisite for setting up the 40-foot were secured.

Saturday, the 19th, was a red-letter day for us, as well as for our countrymen throughout the world. With his usual thoughtful care,

Mr. Franklin-Adams, before leaving England, had arranged that a concise daily telegram should be sent to him giving the latest war news. These telegrams were at once communicated to both camps as well as to the "Theseus," and it is needless to say with what keen interest they were received and discussed. We were preparing for lunch at the comfortable little restaurant where we lodged when the telegram announcing the relief of Mafeking was received. Immediately we all rushed into the entrance hall, where we gave three hearty British cheers, greatly to the astonishment of our Spanish friends, who were quite at a loss to understand what all the cheering and excitement meant.

By Monday the 21st all our heavier concrete foundations were finished, and we had a clear week in which to adjust and test our appliances. The weather had also become much clearer, particularly in the afternoon, when it was important to check the final adjustments of the long telescope at the hour corresponding to that of the eclipse. Eventually all the adjustments were completed and tested by the 27th, on the afternoon of which day we had the satisfaction of seeing the sun's image traverse the plate-holder of the 40-foot precisely at the computed rate, and at the exact distance from the centre line corresponding to the sun's declination at the time.

On the 26th we received a visit from the Civil Governor of the Province of Alicante, who was desirous of seeing our apparatus and satisfying himself that everything possible was being done for our comfort and convenience. On the same day a party of French astronomers came over from Elche to see our camp and compare notes. We much regretted that time did not permit our returning their friendly visit.

Meanwhile, Mr. Heath and Mr. Franklin-Adams had erected the equatorial stands to carry their apparatus. Mr. Heath was provided with a 6-inch photo-visual telescope by T. Cooke and Sons, arranged to photograph the corona in the primary focal plane; while Mr. Franklin-Adams' equipment consisted of a number of cameras, several of them of large aperture, designed for obtaining pictures of the coronal rays and the sun's surroundings generally. He had also several very accurate thermometers mounted on a suitable screen.

The exact duties of each member of the camp were repeatedly rehearsed in accordance with the beats of a metronome, the indications of which were shouted out by a seaman on the plan devised by Sir Norman Lockyer for regulating the numerous operations at his camp. As most of the observers had already practised at their respective instruments, even the first general rehearsal went off much better than we could have expected. The whole credit of this is due to our naval assistants, who, from being trained to act promptly and in concert, readily appreciated the exact nature of the new duties entrusted to them.

In the night all the plate-holders were duly filled and arranged in order.

For about a week before the day of the eclipse the closely approximate time of Greenwich mean noon was signalled to us from the ship. This proved of the greatest value, as it relieved the camps of the necessity of making independent time determinations.

From the moment at which the erection of the instruments was commenced four members of the "Guardia Civil" were told off by the Spanish authorities to watch over the safety of our gear. A single wire cord stretched round the area occupied by the instruments served as the line of demarcation, within which unauthorised persons were not allowed to come. On the day of the eclipse this line was thrown somewhat farther back at the suggestion of our Spanish friends.

The weather on the momentous 28th was all that astronomers could desire. With the greatest care all our apparatus was revised. The end of our barn had been smoothed over with stucco so as to present a white expanse some 30 feet in width by 15 feet in height on which to observe the shadow bands. The azimuth of this wall was very exactly S. 40° W., and as mid-totality occurred in azimuth 92° 10′, the position of the wall was very favourable for the observations in question. We also put up a white screen some 14 feet square, projecting at right angles to the northern end of the wall, and whitened the ground in the angle thus enclosed, thereby giving three planes on which we hoped the bands might be seen. Two officers of the "Theseus," who for some days previously had practised marking and recording imaginary shadow bands, were entrusted with the duty of recording the real bands as they appeared on the white surfaces. They were provided with brushes attached to long poles, and with pots of coloured wash—blue for the beginning of totality and red for the end.

I undertook to observe the first contact with a small telescope of 2 inches aperture.

This occurred $10^{s}{\cdot}4$ before the computed time but the discrepancy caused no surprise, as the moon's limb was very rough at the point of contact, and there was the chance that our chronometer-time might be out a second or two. In view of the very important work before us, no photographs of the partial phase were attempted.

I have a note that at twelve minutes before totality the sky began to darken very rapidly, the darkness increasing more and more visibly during the last minutes before the total phase. Five minutes before totality, at the word "Stations," everyone took up his assigned post. The large crowd of spectators who had collected during the last hour or two pressed closer in to the boundary wire—some of them still expressing their doubts as to whether the eclipse would really be total or not.

Eighty-three seconds before the computed time of second contact I

gave the signal "Start the clock" to McPherson, who was in the dark room of the 40-foot. At this moment Mr. Franklin-Adams gave a few strokes on a large bell, and called out "*Silencio!*" I must here say that this call was immediately obeyed in the most courteous way by the assembled crowds, who maintained a perfect silence until the important phase was over.

One minute before totality, at the signal "Chronograph," McPherson registered the position of the moving plate-holder. Sixteen seconds before totality, when, according to Mr. Fowler's computation, the diminishing crescent should subtend an arc of 90°, I gave the signal "Stand by;" five seconds before totality, corresponding to 55° of a crescent, the signal "Ready" was called, and at the disappearance of the last glimpse of sunlight I gave the final signal of "Go!"

From this moment the sailor in charge of the metronome announced every fifth second during the first minute, and then every second until the seventy-fifth, when he called "Stop!"

One minute and twenty-four seconds after the signal, I gave to McPherson the final signal "Chronograph," which he again recorded on the moving plate-holder, assuring himself at the same time that it was still moving at the regular speed. While I was giving the earlier signals just mentioned, I noticed a very interesting feature in the diminishing crescent. When the luminous crescent was reduced to a mere line, an exceptionally brilliant bead of light became detached from the rest, continuing to shine like a bright star for perhaps four or five seconds, and probably disappearing nearly at the same time as the rest of the crescent. It was doubtless due either to the passage of the sunlight through a very deep valley on the moon's limb or to the interruption of the crescent by a high range of lunar mountains. Whatever its origin it presented an extreme case of the well-known phenomenon of "Baily's Beads."

What struck me most, both in the late eclipse and in that of 1898, was the sudden transition from the swiftly changing phenomena attendant on the disappearance of sunlight to the steady unvarying aspect of the corona. During the last few minutes of the partial phase all the phenomena are in a state of rapid change—the light decreases in a swift geometrical ratio, the last shred of the sun's limb disappears, the prominences burst into view, and all at once the corona stands before one fixed and relatively unchanging during the whole of totality.

The corona, as seen with the naked eye, presented a striking resemblance to the pictures of the corona of 1878. Below was a broad double streamer, like the outspread tail of a dove, symmetrical to the sun's equator, while opposite to this was a single large pointed streamer involved in a much fainter dove-tail symmetrical to the one below. The spectrum shown by an excellent direct-vision prism about mid-

totality struck me as being very continuous, for I did not see the K 1474 ring. In common with all other observers, I was struck by the extreme brightness and the red colour of Mercury some $2\frac{1}{2}^\circ$ preceding the Sun, while near the zenith Venus blazed in the purest white.

Turning to the photographic results, three successful negatives of the prominences and the corona were obtained with the 40-foot, with exposures of $5^s{\cdot}0$, $18^s{\cdot}6$, and $3^s{\cdot}0$ respectively. On the whole, the long exposure gives the best picture; in the original negative the light of the great equatorial streamers can be traced to a distance of about one solar diameter from the moon's limb, while the detail of the shorter streamers is shown with considerable precision. The short exposures naturally bring out the shorter rays that are to some extent lost in the brightness due to the long exposure.

There are also twenty-four spectrograms taken with a direct-vision prism drawn in front of the object glass of the 40-foot. Of these, two groups of ten each were secured, one set as totality was coming on and the other immediately after it had ended. They were taken on plates measuring 8 inches by 16 inches, so arranged as to be moved transversely in the plate-holder between each exposure. The "height" of each spectrogram is 0·3 inch, while an interval of $\frac{1}{2}$ inch is allowed between the different pictures. The remaining four spectrograms were taken after totality with the 40-foot acting as a prismatic camera. The two earlier ones show H, K and other lines extending beyond the continuous spectrum, while the two last are of little interest except for finding how long after the end of totality it is possible to obtain useful spectrograms.

In developing these plates, and in making the copies and slides* from them, we had the advantage of the skilful assistance of Mr. John Banks, photographer, of Edinburgh.

McPherson's position inside the dark room of the 40-foot gave him the unique opportunity of watching the actual image of the sun's appendages as it imprinted itself on the sensitive films. At the time of making the exposure of nearly nineteen seconds at mid-totality he describes the picture as comparatively dark—very little of the corona being visible; the larger prominences were, however, noticed, although they were not nearly so bright as afterwards. In the last exposure, near the end of totality, the prominences appeared of a bright flaming red colour, and the picture on the plate was altogether a splendid sight. Mr. McPherson was watching the prominences under the impression that there were still five seconds to spare, as the time-keeper at the metronome was counting seventy, and we expected the eclipse to last seventy-five seconds, when all at once a sudden increase

* The best of these slides, as well as contact copies of the larger negatives, were exhibited at the meeting.

of brightness took place on the moon's limb—white light seeming to curl over the edge of the moon's disc. Immediately concluding that the total phase was all but over, he let go the cord and closed the shutter. When working with the prism the exposures were far too short to permit of seeing the images.

The spar camera was in charge of William Slaughter, petty officer of the "Theseus"; it could not possibly have been in better hands, for in spite of the lightness of the 3-inch equatorial mounting and the delicate clock movement by which it was carried, he exposed all his plates without deranging the instrument in the slightest degree. Six spectrograms were obtained in all, several of which contain many ultra-violet lines belonging to the chromosphere, or possibly to the lower layers of the corona.

Pending the presentation of the report on the shadow-bands which is in my hands, but which I should like to supplement by a short computation, I may say that the two officers of the "Theseus," Mr. Green and Mr. Alexander, succeeded in marking the course of the shadow-bands on the vertical wall both at the beginning and at the end of the total phase. As totality came on, the faint rippling bands moved to the right upwards, the direction of motion making an angle of 20° to 30° with the vertical; at the end of the dark phase the motion was in the opposite direction—to the left downwards—the motion in both cases being at right angles to the lines. The lines appeared in short wavy fragments. Quite at the last, a little after the main body of the lines had disappeared, there came a solitary thicker line, more distinct than the rest, and moving less rapidly in a direction inclined 47° to the vertical, but otherwise in the same general direction as the rest of the lines. The wall was photographed, but although the negative shows the red lines distinctly enough, the full blue colour used at the beginning of totality, can scarcely be seen in the photograph. No bands were satisfactorily made out on either of the two other planes.

The warmest thanks of our party are due—to the Admiralty for all the assistance given to us; to the officers and crew of H.M.S. "Theseus" for their hearty co-operation, which contributed so largely to the success of our endeavours; to the British Vice-Consul at Alicante; to the Spanish authorities and to our Santa Pola friends for their untiring courtesy and kindness; and to the "Orient" Steamship Company for their very liberal concession in carrying our bulky impedimenta practically free of cost.

"Total Eclipse of the Sun, 1900, May 28. Preliminary Account of the Observations made at Ovar, Portugal." By W. H. M. Christie, C.B., M.A., F.R.S., Astronomer Royal, and F. W. Dyson, M.A., Sec. R.A.S. Read at Joint Meeting of the Royal and Royal Astronomical Societies, June 28, 1900. MS. received October 18, 1900.

[Plates 21—24.]

## I. *General Arrangements.*

An expedition to observe the total solar eclipse of May 28 having been sanctioned by the Admiralty, it was arranged, in concert with the Joint Permanent Eclipse Committee, that the Royal Observatory party should take photographs of the corona on a large scale for structural detail, and on a smaller scale for the coronal streamers, and should also photograph the spectrum of the "flash" and of the corona. The programme thus naturally divided itself into two parts, Mr. Christie, assisted by Mr. Davidson, taking charge of the first part, and Mr. Dyson of the second.

The party are much indebted to the Portuguese Government for the liberal arrangements made for the conveyance of the observers and their instruments in Portugal free of all charge to and from their observing station at Ovar, and for the great assistance rendered in erecting the instruments, and for a daily time-signal from the Lisbon Observatory direct to the observing station.

They are also indebted to Mr. Frank Rawes, of Oporto, for making all arrangements for a suitable observing station at Ovar, and for much thoughtful provision for the comfort and convenience of the observers.

The party further received valuable assistance from Mr. J. J. Atkinson, who went with them from England, and from Mr. Arthur Berry, who joined them in Portugal on May 20; they readily joined in all the work of the expedition, such as the erection of huts, instruments, &c. The party are also indebted to them, and to Mrs. Kennedy and to Mr. Rawes, for assistance in the observations on the day of the eclipse.

*Itinerary.*—The observing huts and instruments were sent to Southampton on May 8, with the exception of the 16-inch cœlostat mirror, and two boxes of photographic plates which were taken with the observers' personal baggage. The observers left Greenwich on the morning of Friday, May 11, sailing from Southampton by the Royal Mail steamship "Clyde," and reaching Lisbon about noon on May 14. After an interesting visit to the Royal Observatory at Tapada, Lisbon, on May 15, the observers left for Ovar on the evening of May 16, and arrived there on the morning of Thursday, May 17.

They left Ovar for Lisbon on Tuesday evening, May 29, the day after the eclipse, and left for England by the Royal Mail steamship "Magdalena," on Friday, June 1, reaching Southampton on June 4, and Greenwich on June 5. While at Lisbon, the Astronomer Royal had the honour of an audience with His Majesty the King of Portugal.

*Station.*—The station chosen was at Ovar, in Portugal, near the extreme westerly point of the line of totality in Europe, having the advantage of the longest totality.

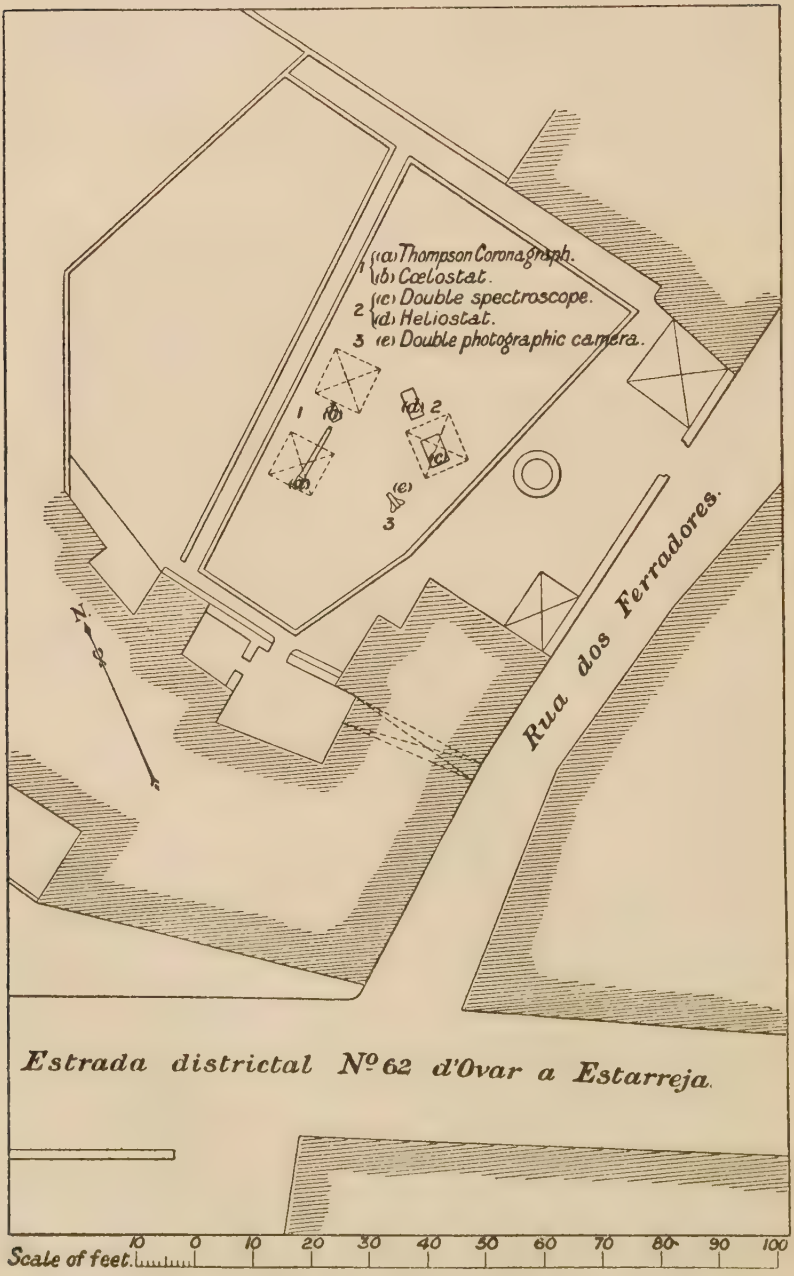
Ovar is a town about twenty miles south of Oporto, on the railway line to Lisbon; it is situated on a sandy plain, which stretches to the sea, the nearest point of the coast being about three miles distant. The meteorological conditions of this station proved to be good, the sky being clear on eight of the thirteen days during which the observers were there.

The station occupied by the observers was the garden of Mr. Silveiro's house; its position, taken from the Ordnance map in conjunction with plans of the town, furnished by the Public Works Department, is lat. 40° 51′ 30″ N., and long. 8° 37′ 3″ W., and is about $1\frac{3}{8}$ m. from the central line of the eclipse.

*Erection and Disposition of Huts and Instruments.*—It was found on arrival at the station that the loose sandy soil reached to a depth of at least 18 feet, thus rendering the erection of concrete or masonry piers unsuitable, as well as impracticable. The ground was accordingly cleared on May 17, the day of arrival, and thoroughly rammed; the wet weather which had prevailed previous to the arrival, rendered this the more effectual. On the same day the instruments and materials for the huts were brought from the railway station, half a mile away, in ox-waggons, and partially unpacked. The arrangement of instruments and huts was also roughly marked out.

On the next day, May 18, the huts to cover the instruments were erected, and boxes filled with stones, on which to mount them, were placed in position, The huts were light wooden frames, covered with Willesden waterproof canvas; they were fitted together at Greenwich before starting, and the woodwork marked, so that they were readily fixed up. There were three huts exactly alike structurally, each being 8 feet square and 8 feet high, rising to 10 feet at the gable; the canvas was thrown over the top and sides in two lengths, and tacked down to the woodwork; the ends of the huts were arranged with panels when necessary, which could be removed as required. Two of these huts, without any canvas at the adjacent ends, were bolted together, forming one large hut 16 feet by 8 feet, to cover the coronagraph and 16-inch cœlostat. For observation the bolts were removed, and the hut over the cœlostat moved back a few feet. The spectrographs were in the third hut, and the heliostat supplying them was outside the hut,

PLAN OF ECLIPSE STATION AT OVAR, 1900, MAY 28.


1 (a) Thompson Coronagraph.
(b) Cœlostat.
2 (c) Double spectroscope.
(d) Heliostat.
3 (e) Double photographic camera.
Rua dos Ferradores.
Estrada districtal Nº 62 d'Ovar a Estarreja.
Scale of feet.
10 0 10 20 30 40 50 60 70 80 90 100

and provided with a light canvas cover when not in use. The equatorial with the double tube for the small-scale photographs of the corona was covered with a sheet of waterproof canvas when not in use. The arrangement of the different huts and instruments is shown in the accompanying plan.

The instruments were all erected on May 19, the observers thus having a clear week to adjust them, and to rehearse the observations.

*Personnel.*—The following list gives the names of those who took part in the observations :—

W. H. M. Christie :—Thompson coronagraph. Large scale photographs of corona.

F. W. Dyson :—Double photographic spectroscope. Spectrum of "flash" and of corona.

C. Davidson :—Double camera. Small scale photographs of corona to show extension.

J. J. Atkinson :—Assisted Mr. Dyson, moving plate-holders and changing plates for the flint prism spectroscope.

A. Berry :—Counted seconds for first half of totality, and then set the heliostat for second contact.

Mrs. Kennedy :—Counted seconds for second half of totality.

Frank Rawes :—Read thermometers during eclipse.

Four Portuguese Soldiers :—Handed plate-holders during totality for Mr. Christie and Mr. Davidson respectively.

The following was the method of procedure, which was carefully rehearsed on several occasions previously. The observers were stationed at their instruments, and Mr. Christie watched the diminishing crescent of the sun on the ground glass of his coronagraph. He had a paper scale on which the lengths of the crescent were marked, computed for the intervals 3 mins., 2 mins., 1 min., 45 secs., 30 secs., 25 secs., 20 secs., 15 secs., 10 secs., before totality ; at 15 secs. the length of the crescent was 2·64 inches, and at 10 secs. before totality 2·30 inches. Having previously given the signal, "Get Ready," Mr. Christie called out "Ten" at 10 secs. before totality, which was the signal to Mr. Dyson to begin the exposures for the "flash." At totality Mr. Christie again gave the signal (the monosyllable "Tup" was used) and Mr. Berry started a metronome which had been carefully rated to give seconds, and proceeded to count up to 50. Mrs. Kennedy took up the count at 51, and continued counting as far as 100, which had been estimated as 10 secs. beyond totality. While the count was proceeding, exposures at the several instruments were made, as described in the separate reports

*The Day of the Eclipse.*—It was quite clear in the early morning, but some light cirrus clouds collected later, causing the observers some apprehensions. There was some light cloud in the sky during totality,

but there is no reason to suppose that it interfered seriously with the observations.

The first contact occurred at $2^h\ 6^m\ 20^s$ Lisbon Mean Time, and was observed by Mr. Christie on the ground glass of the coronagraph. The time of commencement of the total phase was not accurately noted; the duration was observed (by means of a stop-watch) and found to be $84\frac{1}{2}$ secs., during which the programme detailed below was carried out. After totality photographs were taken for orientation. The fourth contact was at $4^h\ 36^m\ 13^s$ Lisbon Mean Time. There was a good deal of light during totality, the diminution of light being similar to that occurring during a heavy thunderstorm in summer. The temperature fell about 8° during the eclipse.

During totality Mercury and Venus were seen, Mercury especially being very brilliant. The observers had not much opportunity of observing the attendant phenomena of the eclipse, and with the assistance which was kindly given them were only just able to provide adequately for the working of the instruments.

## II. *Photographs of the Corona.*

The programme of observations was composed of two distinct parts:—

(1.) Photographs of the corona on a large scale to show structural detail.

(2.) Photographs on a smaller scale with rapid lenses to show the coronal streamers with the greatest possible extension.

### (1) *Large-scale Photographs.*

(These were taken by Mr. W. H. M. Christie.)

The instrument used for (1) was the Thompson photographic telescope, with object-glass of 9 inches aperture and 8 feet 6 inches focal length, belonging to the Royal Observatory, in combination with a concave telephoto lens by Dallmeyer, of 4 inches aperture and 16 inches focus, fitted as a secondary magnifier, to give an image of the Sun 4 inches in diameter, with a field (for full pencils) of 14 inches diameter. The total length of the coronagraph was 12 feet—the equivalent focal length being about 36 feet. A cœlostat with 16-inch plane mirror (made by Dr. Common) was employed to reflect the rays into the coronagraph, which was mounted (on boxes filled with stones) so as to point to the mirror at an angle of depression of about 5°, and at an azimuth of about 56° West of South for the day of the eclipse. The camera was furnished with five plate-holders to take $15 \times 15$ inch plates or for the shorter exposures $12 \times 10$ inch plates in a carrier.

The five slides for photographs of the corona during totality were

# THE SOLAR CORONA.

1900 MAY 28TH.

*Reduced to $\frac{3}{5}$ size from Photograph No. 4, taken at Ovar, Portugal, by* W. H. M. CHRISTIE.
*Exposure 12 secs. Thompson Coronagraph.*
*Aperture 9 in. Equivalent focus 36 feet.*

exposed as below, the exposures being given by the observer with the exposing shutter of the plate-holder, and the times noted by him, counting from the commencement of totality.

| | Exposure. | | | | |
|---|---|---|---|---|---|
| | Beginning. | End. | Duration. | Plate. | |
| No. 1..... | 7$^s$ | 8½$^s$ | 1½$^s$ | Lantern ..... | 12 in. × 10 in. |
| 2..... | 16 | 22 | 6 | Empress ..... | 12 „ × 10 „ |
| 3..... | 30 | 50 | 20 | Sandell's Triple-coated | 15 „ × 15 „ |
| 4..... | 56 | 68 | 12 | Special Rapid ..... | 15 „ × 15 „ |
| 5..... | 76 | 78½ | 2½ | Lantern ..... | 12 „ × 10 „ |

As soon as possible after totality a second plate was put in No. 5 plate-holder, and exposed twice on the sun for orientation (with driving clock stopped for 3 min. between), the exposure being as short as possible (⅓ to ½ sec.), and the aperture reduced to 2 inches.

"Abney squares" were put on Nos. 1, 3 (twice), and 5, after return home.

No. 1 ..... 300$^s$ exposure at 5 ft. to standard candle.
No. 3 ... 5$^s$ and 30 „ 5 „ „
No. 5 ..... 300 „ 3 „ „

The plates were all developed after return home, hydroquinone dilute being used. Nos. 1 and 5 unfortunately blistered badly in development, especially No. 1, though every care was taken, the developer being at a temperature of 60°. It is to be remarked that other plates developed at the same time under precisely similar conditions were free from blistering. No. 2 is to a certain extent disfigured with spots on the plate, which, however, do not materially interfere with the coronal detail.

No. 4 shows fine detail in the polar plumes and coronal streamers extending to nearly a diameter of the Sun from the limb. No. 3 shows nearly the same.

No. 5 shows very fine detail in the prominences in the S.W. quadrant, with gradation of brightness merging into the coronal structure close to the limb, thus showing a continuity between the two phenomena, and affording fresh evidence of the association between coronal streamers and prominences, which was indicated in the photographs of the 1898 eclipse.

It should be mentioned that the coronagraph was carefully focussed in the same manner as for the eclipses of 1896 and 1898,* by means of the image of an object (gauze net) in the plane of the plate reflected from the plane mirror of the cœlostat. The focus was thus obtained with great accuracy after two or three trials, and it was found that the field was remarkably flat.

* 'Monthly Notices R.A S.,' vol. 57, p. 105; 'Roy. Soc. Proc.,' vol. 64, p. 8.

(2) *Small-scale Photographs to show Extension of the Corona.*

(These were taken by Mr. C. Davidson.)

The double camera, used in former eclipses, was adapted to carry a Dallmeyer rapid rectilinear lens of 4 inches aperture and 34 inches focus, working at f/8 in one-half of the tube. This lens was lent by the Royal Astronomical Society, the two halves, which had been used separately in former eclipses since 1882, having been reunited for the present eclipse.

In the other half of the camera tube there was mounted a new "Unar" lens by Ross, of 2·4 inches aperture and 12 inches focus, working at f/5.

Four plate-holders, each taking a pair of 16 × 16 cm. plates side by side were used during totality, both plates being exposed by a quarter turn of a shutter. A fifth plate-holder was used to obtain double images of the Sun for orientation as soon as practicable after totality.

The double camera was mounted on the equatorial stand of one of the Dallmeyer photo-heliographs, originally made for the Transit of Venus 1874, the middle section of the stand being removed to make it more handy.

Both lenses were carefully focussed on star-fields, the final adjustment being made by inserting thin metal rings beneath the flange of the lens.

The four slides for photographs of extension of the corona were exposed as below, the exposures being noted by the observer, counting from the commencement of totality.

| | Exposure. | | | |
|---|---|---|---|---|
| No. | Beginning. | End. | Duration. | Plate. |
| 1..... | 3ˢ | 8ˢ | 5ˢ | Sandell Double-coated. |
| 2..... | 18 | 48 | 30 | „ Triple-coated. |
| 3..... | 57 | 72 | 15 | „ „ |
| 4..... | 80 | 83 | 3 | Empress. |

Shortly after totality the fifth slide with Sandell double-coated plates was exposed three times on the Sun for orientation at intervals of $3\frac{1}{2}$ mins. with the driving clock stopped. In this case both lenses were stopped down to their smallest aperture, *i.e.*, f/64 for the "Unar" lens and f/44 for the Dallmeyer, and the exposure was as short as possible (about $\frac{1}{4}$ sec.).

"Abney squares" were put on Nos. 2 and 4 after return home.

No. 2 30 secs. exposure at 5 feet to standard candle.

No. 4 10 „ „ „ „

The photographs with short exposure No. 4—3 secs. are the most

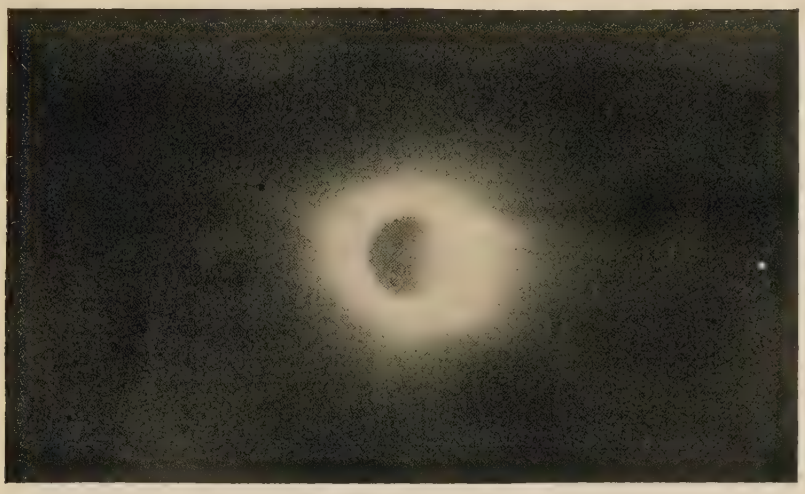
ECLIPSE OF SUN. OVAR. 1900 MAY 28.

N

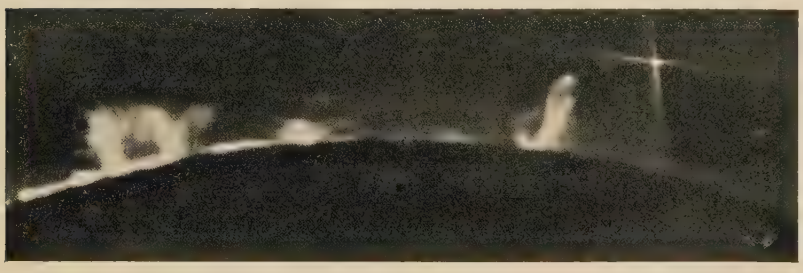
E

W

S



Photograph of Corona, obtained with Dallmeyer rapid rectilinear lens of 4 inches aperture (enlarged 1½ times from photograph No. 1). [The planet Mercury is shown on the western side of the photograph.]



Photograph of Prominences in S.W. Quadrant (enlarged 2½ times from photograph No. 5, taken with the large coronagraph). [The spot with cross rays on the right-hand side is a defect in the photographic plate.]

successful, and show the greatest extension, that taken with the "Abney" lens showing rays which can be traced on the east side to a distance of more than 2° from Sun's centre, and on the west side to a distance of fully $1\frac{3}{4}°$. This is further than they could be traced visually under the atmospheric conditions at Ovar, where the observers traced them to a distance estimated at $\frac{2}{3}$ of distance of Mercury from centre, *i.e.*, $1\frac{1}{3}°$.

### III. *The Spectroscopic Cameras.*

(By F. W. Dyson.)

*Instruments.*—The spectroscopes used were two kindly lent by Captain Hills, and employed by him in the Indian Eclipse of 1898, January 22. The details of their adjustments as used at Ovar are as follows:—

| | Spectroscope No. 1. | Spectroscope No. 2. |
|---|---|---|
| Objective ..... | Cooke, achromatic, $4\frac{1}{2}$ in. aperture, 6 ft. $2\frac{1}{4}$ in. focus. | Single quartz lens, 5 in. aperture, 4 ft. $7\frac{3}{4}$ in. focus. |
| Collimator and camera lens | Single quartz lens, $2\frac{1}{2}$ in. aperture, 30 in. focus. | Single quartz lens, 3 in. aperture, 36 in. focus. |
| Slit ..... | $1\frac{1}{2}$ in. by 0·0014 in. | 2 in. by 0·0012 in. |
| Prisms ..... | Two dense flint prisms of 60°, $4\frac{1}{2}$ in. base, $2\frac{1}{2}$ in. height. | Four double quartz prisms of 60° (each prism being composed of two half-prisms of right- and left-handed quartz), $3\frac{1}{2}$ in. base, $2\frac{3}{4}$ in. height. |
| Prisms at minimum deviation for | $H_\gamma$ ($\lambda$ 4340). | $H\zeta$ ($\lambda$ 3889). |

The width of the slits were adjusted by a method given by Mr. Newall. The third diffraction image of the slit, viewed by putting the eye near the position of the plate, was made to come on the edge of the object-glass by altering the width of the slit, and the slit left at this reading.

The length of the spectrum on the plate for spectroscope No. 1 was $3\frac{1}{4}$ inches from $H\beta$ ($\lambda$ 4861) to K ($\lambda$ 3934), and for spectroscope No. 2 $2\frac{1}{4}$ inches from $\lambda$ 4100 to $\lambda$ 3500.

Both spectroscopes were mounted horizontally, and were supplied with light by a heliostat furnished with a 12-inch flat mirror.

*Erection and Adjustment of Instruments.*—As the nature of the ground was unsuitable for brickwork or concrete piers, three of the boxes in which the instruments were carried were filled with stones and the

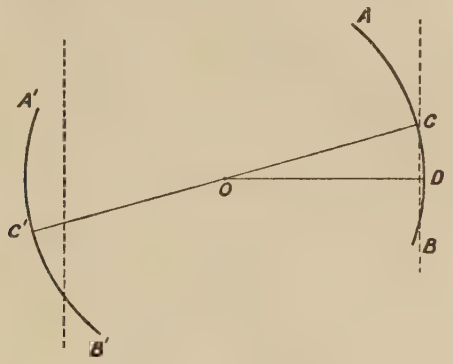
instruments erected on them. On one of these—a large clock case, 5 feet long, $2\frac{1}{2}$ feet broad, and $1\frac{1}{2}$ feet high—the heliostat was placed, a light wooden frame holding the two objectives. This was covered when not in use by Willesden canvas on a light wooden framework which could be readily lifted on and off. The spectroscopes stood on a mahogany table, 5 feet by 4 feet, which rested on the topmost of two boxes. The boxes were of such a height that the middle of the slits of the two spectroscopes were respectively half an inch below and half an inch above the centre of the mirror. This had to be arranged somewhat carefully, as a 5-inch and a $4\frac{1}{2}$-inch lens had to be supplied with light by a 12-inch mirror whose normal at the time of the eclipse was inclined more than 40° to the incident and reflected rays. The spectroscopes were in a hut, 8 feet square, made of Willesden canvas, facing north and south, and with the north side open when the instruments were in use.

The adjustment of the polar axis of the heliostat was made by means of an attached theodolite, the altitude of the axis being first set to the latitude, and the azimuth then adjusted by observing the sun's declination at different hour-angles from $9^h$ to $16^h$. In this way the instrument was readily adjusted till the observed declinations of the sun agreed to within 2′ with those of the Nautical Almanac throughout the above range of hour-angle. The stability of the mounting of the instrument on the sand was quite satisfactory, only very small changes in level occurring, and no perceptible changes in azimuth. The only difficulty experienced with the heliostat was in the driving, which is not very satisfactory at large azimuths.

*Programme of Exposures.*—The two spectroscopes were adjusted to be as nearly as possible on the sun's limb simultaneously, and the programme of exposures was the same for both. The cameras of the two spectroscopes were provided with rack movements, so that a number of exposures could be made on the same plate. A flap was arranged so that the exposures for both spectroscopes were made at the same time. The programme, as arranged with an expected duration of totality of 90 secs., was as follows :—

Ten exposures were made of 1 sec. duration beginning 10 secs. before totality at about 1 sec. apart for the spectrum of the "flash" at the beginning of totality. The plates were then changed, and at 20 secs. from the beginning of totality the plates were exposed for 50 secs., *i.e.*, till 70 secs. from the beginning of totality for the spectrum of the corona. The plates were again changed and the image on the slit moved by Mr. Berry by means of the slow motion of the heliostat, and ten exposures of 1 sec. duration, beginning at 80 secs. after first contact, were given for the spectrum of the "flash" at second contact. The conditions under which the "flash" was photographed, as determined by the circumstances of the eclipse at Ovar and

the instruments used, are shown in the accompanying diagram, which is enlarged about four times.




O is the centre of the sun's disc; AB is the bright arc as seen 10 secs. before totality, and is 70°. The centre of the arc, C, which is about 1° from the equator, is 16° above the point D where the arc is vertical and could be made to touch the slit. The slit, which is represented by dotted lines, cut the bright arc between C and D, the horizontal distance between C and D being $\frac{1}{50}$th of an inch. The time for the first exposure, viz., 10 secs. before totality, was given to the observers by the Astronomer Royal from the length of the rapidly diminishing arc as seen by him on the ground glass of the coronograph. This time appears to have been given correct to about 1 sec.

The position of the image on the slit was not changed for the spectrum of the corona, which was obtained near the point of second contact.

For the "flash" at third contact the slow motion of the heliostat was used, making the sun's image travel in the direction OC of the diagram, the amount of the displacement being determined by watching the sun in the attached theodolite. The position of the slit relatively to the bright arc is shown in the second diagram; in this case the slit was not nearly tangential to the sun's limb.

The photographic plates used were Ilford "Empress" for the first "flash" photograph with the flint spectroscope and for both the "flash" photographs with the quartz. An Ilford "Ordinary" was used for the second "flash" photograph with the flint. Cadett "Lightning plates" were used for both photographs of the corona spectrum.

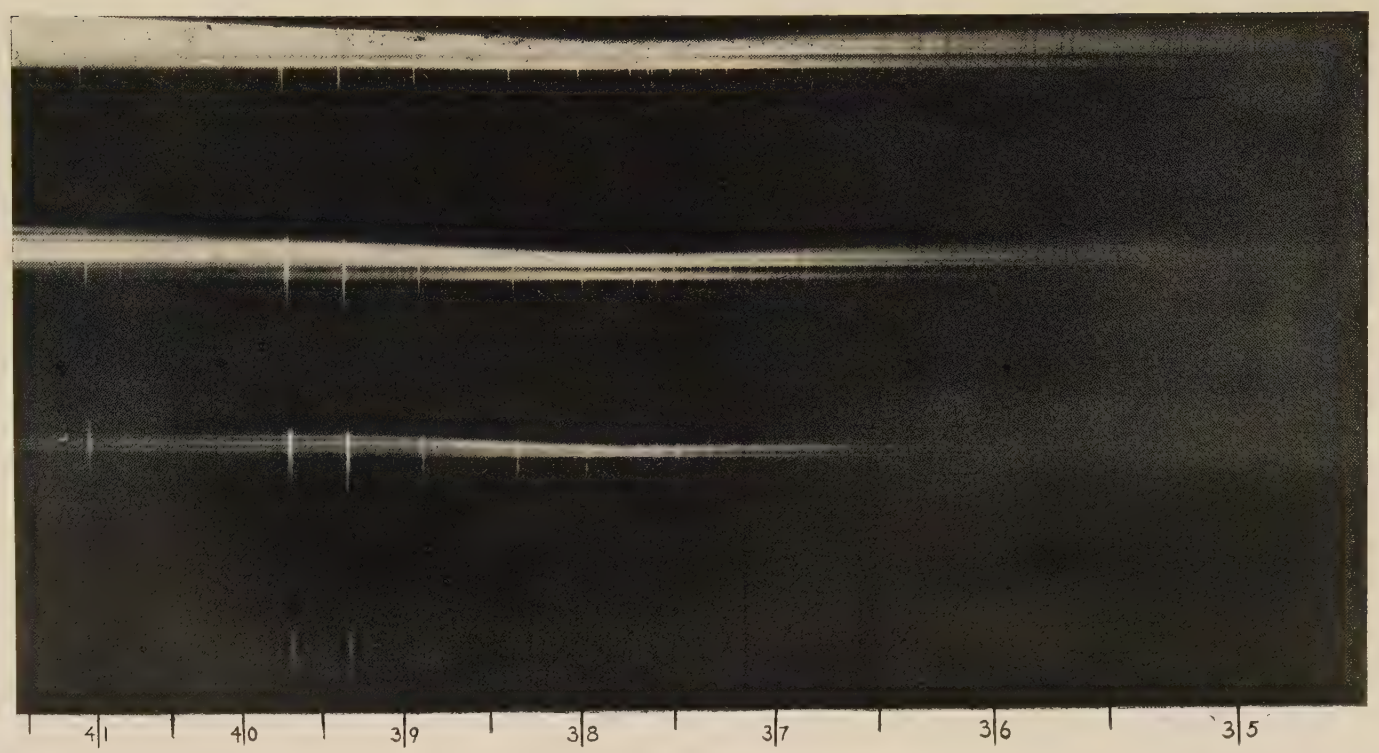
*Spectrum of the Sun's Limb.*—The series of spectra of the limb show a large number of lines, but they have not yet been examined in detail. With the flint spectroscope, a spectrum is obtained extending from F to K. This is good from F to *h*. With the quartz the spectrum reaches from *h* to λ 3300, and is in good definition to about λ 3450. The photographs taken with the quartz spectroscope at the

beginning of totality are an interesting series. They show a long series of hydrogen lines (26 beginning at *h*), and a large number of iron and titanium lines. The difference in behaviour of these two metals is shown in a striking manner, the titanium lines, like the hydrogen lines, being bright in the whole series of photos. beginning 10 secs. before totality, while the iron lines are reversed in the earlier photographs. Titanium lines at wave-lengths 3685·30, 3761·46, and 3759·42 are specially bright. A reproduction is given of part of this series of photographs. (Plate 23).

*The Corona Spectra.*—Reproductions of these spectra are given in the accompanying plate (Plate 24). With the flint spectroscope a continuous spectrum is obtained from F to H. Eight bright lines are distinctly shown stretching right across the continuous spectrum, and several shorter lines in the densest part. The line 1474 K is not shown, probably because plates specially sensitive in the green were not used. The wave-lengths of the lines have not yet been determined. The positions of the corona lines are indicated on the plate and can be seen in the top band, though only faintly.

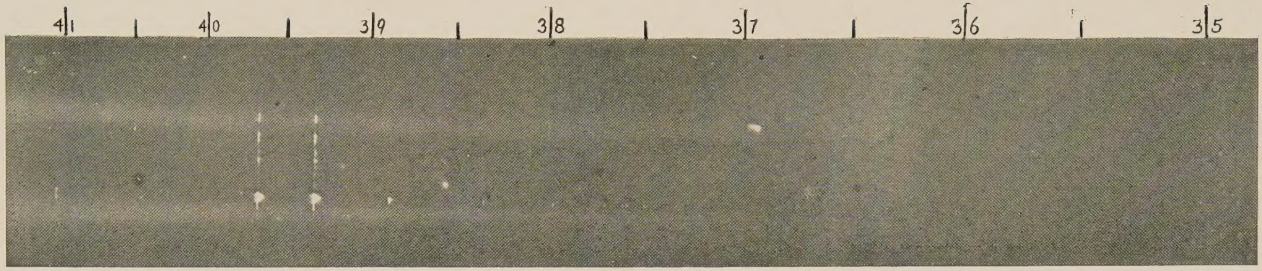
With the quartz spectroscope a continuous spectrum is shown which can be faintly traced as far as λ 3600. Strong bright lines are shown at λ 3987 and λ 3801.

Harrison and Sons, Printers in Ordinary to Her Majesty, St. Martin's Lane.

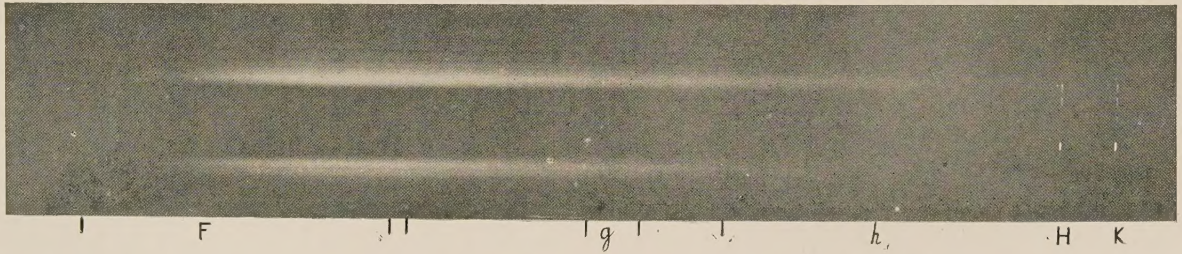



Series of Spectra of Sun's Limb, obtained with Quartz Spectroscope, near the beginning of totality (enlarged $2\frac{3}{4}$ times).
(Approx. $5^s$, $3^s$, $1^s$ before totality, and $1^s$ after.)

ECLIPSE OF SUN. OVAR. 1900 MAY 28.




Spectrum of Corona, taken with the Quartz Spectroscope (enlarged $2\frac{3}{4}$ times).




Spectrum of Corona, obtained with Flint Spectroscope (enlarged $1\frac{1}{2}$ times).

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